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PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
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MEETINGS

of the

American Institute of Electrical Engineers

(See Announcements This Issue)

WINTER CONVENTION, New York, N. Y.
February 13-17, 1928

ST. LOUIS REGIONAL MEETING, District No. 7
March 7-9, 1928

BALTIMORE REGIONAL MEETING, District No. 2
April 17-19, 1928

NEW HAVEN REGIONAL MEETING, Northeastern District No. 1, May 9-11, 1928

SUMMER CONVENTION, Denver, Colo.
June 25-29, 1928

PACIFIC COAST CONVENTION, Spokane, Washington, Aug. 28-31, 1928

MEETINGS OF OTHER SOCIETIES

American Engineering Council, Washington, D. C., Jan. 9-11, 1928

American Institute of Radio Engineers, New York, N. Y., Jan. 9-11, 1928

American Society of Civil Engineers, New York, N. Y., Jan. 18-20, 1928

Midwestern Engineering and Power Exposition, Coliseum, Chicago, February 14-18, 1928

American Institute of Mining and Metallurgical Engineers, New York, N. Y., February 20-23, 1928

JOURNAL
OF THE
American Institute of Electrical Engineers

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JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Vol. XLVII JANUARY, 1928 Number 1

Change in Institute Publications Ratified

The opening article in the JOURNAL for November, 1927, gave an outline of the changes proposed for the publications of the A. I. E. E. and these changes were adopted by the Board of Directors at its meeting on December 16th, after a careful canvas of the situation by the Publication Committee. They are being put into effect as rapidly as possible and it is expected the new plans will be in full operation within the next two months.

In order that the changes should be acceptable to the membership, the Board of Directors, invited suggestions and criticisms, and in addition, two hundred letters were sent out by the Publication Committee to some of the most active members, also inviting comments on the proposed changes. The net result of these appeals was 75 letters from a membership of 18,000, which can probably be construed as a vote of confidence in the Institute's committees to carry out its publication policies to the best advantage of all.

Of the 75 replies received, 78 per cent endorsed the suggested changes unqualifiedly and but four or five had objections. These letters also contained numerous suggestions which the Publication Committee acknowledges with thanks to the writers. Most of the suggestions received, however, had been previously considered and rejected for reasons which are more readily apparent to those experienced in the publishing business than to the laity. For example, several of the proposed plans would make the publications ineligible for second class post office entry, while others would require an additional force of employes to handle.

The plan finally adopted, which it is believed will cover the Institute's publication requirements for several years, is predicated on the production of the maximum amount of technical literature for the available money. There is probably a general feeling that the Institute should be the repository for all of the most important contributions to electrical engineering literature, and with this thought in view, the present plans contemplate a gradual increase in volume of material published, limited only by our financial resources.

PAMPHLET COPIES

As soon as practicable, after the receipt of manuscript, pamphlet copies of each paper will be printed, and an important point to be noted is that in every case the pamphlet copy will contain the paper *in full.* Each pamphlet copy will bear a serial number for convenience in ordering and this serial number will appear on the JOURNAL abridgments of the papers and also on an order form to be printed in each number of the JOURNAL. It will then only be necessary to check on the order form the number of the paper desired tear off the form and mail to headquarters in order to obtain any pamphlet copy free of charge. By means of this arrangement every paper is at once available to every member who wants it, and without any expense.

THE JOURNAL

As soon hereafter as the plans can be put into effect the JOURNAL will consist of articles none of which will be over four pages in length. These will consist chiefly of abridgments of the papers presented at conventions and regional meetings, but owing to the condensed form in which they will appear, sufficient space will be conserved for the publication of many section and branch papers of merit, as well as contributions, all of which have been largely crowded out in the past for lack of space. The JOURNAL will therefore contain a resumé, in brief and interesting form, of each of the papers published by the Institute, which it is thought will enable every member to keep abreast of electrical progress in all fields without being bothered by details in which only the specialist is interested. At the same time, any paper the reader may desire in full is immediately available, as explained above. Discussions in the JOURNAL will be in abstract only.

THE TRANSACTIONS

Volume 45 of the TRANSACTIONS for 1927, which is now in course of preparation, will be the last annual volume to be published by the Institute. Thereafter the TRANSACTIONS will be issued quarterly, in pamphlet binding, for which a subscription price of two dollars per year will be charged. In all respects the contents of the Quarterly TRANSACTIONS will be the same as in the Annual TRANSACTIONS, that is, all papers and discussions will be printed in full. Objections have been made in some cases to the pamphlet binding of the quarterly, and to meet such objections arrangements have been made to bind the quarterly in cloth, identical in style with the previous annual volumes, for an additional price of two dollars.

The annual volume for 1927 will include the papers presented during that year from January 1st through the 1927 Summer Convention. This will make a

book of about 1200 pages. The first quarterly will include the papers presented at the Pacific Coast Convention and the Chicago Regional Meeting in the Fall. It is estimated the quarterlies for 1928 will average about 375 pages in size, and will be published in the months of January, April, July and October. One effect of issuing the TRANSACTIONS quarterly is to advance the time of publication about a year, and therefore during the transition period of 1928 the membership will be receiving both the 1927 Annual, and the 1928 quarterlies, so that subscriptions to both will fall due during the same year.

In order that the above program may be put into effect the Board of Directors at its last meeting adopted the following ruling:

> Manuscripts of over 4000 words intended for publication in the JOURNAL in abridged form, must be accompanied by an abridgment of not more than 4000 words, and of a proportionately smaller number of words if illustrations are included.

Hereafter an essential part of all papers submitted will be an abridgment, in accordance with the above ruling, for JOURNAL publication. It is not believed that this will impose any additional burden upon the authors as they now have to prepare abridgments in order to present the papers at meetings in the allotted ten minutes time. The same abridgment, covering the most important features of a paper, would be suitable for JOURNAL publication and for presentation at meetings.

* * * * *

The results of the new publication policy may be briefly summarized as follows:

1. Each member will receive the monthly JOURNAL as at present and such complete pamphlet copies as he may select, without extra charge.

2. Each member subscribing two dollars will receive four QUARTERLY TRANSACTIONS containing all papers and discussions in full that are deemed suitable for this permanent reference work.

3. Each member subscribing four dollars will receive the QUARTERLY TRANSACTIONS bound in cloth identical in style with the annual TRANSACTIONS of previous years.

4. During 1928, both an annual for 1927 and quarterlies for 1928 will be published and subscriptions for both will fall due.

Some Leaders of the A. I. E. E.

Edward Leamington Nichols, Professor Emeritus of Physics, Cornell University, a Member of the Institute since 1887 and its vice-president 1889-1891, was born September 14, 1854, at Leamington, England; his parents, however, were Americans, their home being in New York City, and the boy was prepared for college at the Peekskill Military Academy. In 1871 he entered Cornell, studying under Professor William A. Anthony, then in charge of the Department of Physics. Later in 1887 when Professor Anthony left the chair, his former pupil was chosen to fill the vacancy, continuing as head Professor of Physics until his own retirement. Following his graduation from Cornell, Doctor Nichols went to Germany to continue his studies with such teachers as Wiedermann, Kirchhoff, Helmholtz and Listing. It was under Listing that he received his degree of Doctor of Philosophy from the University of Göttingen. As a Fellow of Johns Hopkins, Doctor Nichols returned to America to continue his scientific work in the laboratory with Professor Henry A. Rowland. Thus, he had the great advantage derived from early association with the leading physicists of both Germany and America, and in the early days when establishing technical courses work in electrical engineering was often combined with the study of physics.

In 1880 Doctor Nichols joined the staff of Thomas A. Edison at Menlo Park, there working with problems appertaining to the incandescent lamp. The following year, however, he was called to the Central University of Kentucky as professor of Physics and Chemistry, in 1883 he was made professor of Physics and Astronomy at the University of Kansas. At Cornell, Doctor Nichols has made exhaustive researches in the fields of electricity and optics. He was the first to investigate alloys with low temperature coefficients of resistance and to show that certain proportions of the ingredient alloys could be obtained even with a zero or negative coefficient. His work dealt with photometry, physiological optics, fluorescence, phosphorescence, luminescence and co-related phenomena. Many of his papers on experimental physics have been published in the scientific journals of Germany, England and America; his books too are well known to the professional world. In 1893 he founded the journal, *Physical Review*, himself editor in-chief. In the same year he became secretary to the Chamber of Delegates of the Electrical Congress at Chicago, and a member of the visiting committee officially appointed by the Bureau of Standards. He obtained his B. A. from Cornell, the degree of LL.D. was conferred upon him from the University of Pennsylvania and his D.Sc. was earned at Dartmouth. He is a Fellow of the American Academy of Arts and Sciences, a member of the National Academy of Sciences, the American Philosophical Society, past-president of the American Association for the Advancement of Science and the American Physical Society; and honorary member of Illuminating Engineering Society and the Optical Society of America. While Doctor Nichols' work has been of great practical value his ideals are research for its own sake. It is his contention, however, that many practical applications of fundamental scientific truths cannot be foreseen and that therefore this same application is but the outgrowth of research which at its inception, might appear to have little or no practical application. He has been rightfully placed among the leading scientists of the age.

Operation and Performance of Mercury Arc Rectifier on the Chicago, North Shore and Milwaukee Railroad Company

BY CAESAR ANTONIONO[1]

Associate, A. I. E. E.

Synopsis.—*Actual operating results and experiences with a mercury arc rectifier feeding a railroad are given in this paper. The rectifier is compared with synchronous converters in regard to efficiency, troubles, maintenance and other points.*

THE application of the mercury arc rectifier is one of the newest developments in the railway power field and very little is yet known about its possibilities and applications in this country.

Other papers presented before the Institute have covered the technical points and details on the subject, so that I shall attempt to confine myself to the rectifier's performance on railway work in conjunction with automatic operation.

The development of the rectifier in this country is very much in its infancy as regards its commercial application. It appears to be used more extensively in Europe, and the extent to which it will be applied here is limited only by the economical and operating results which can be obtained.

In considering its application to any property we naturally compare it with the synchronous converter and motor-generator set designed to serve the same class of service, with which we are familiar.

The advantages of the mercury arc rectifier over the synchronous converter and motor-generator according to previous papers presented before the Institute are:

1. High efficiency over the whole working range,
2. Very high capacity to absorb momentary loads,
3. Insensibility to short circuits,
4. No synchronizing,
5. Simple operation and minimum attention,
6. Noiseless operation and no vibration,
7. Low maintenance cost,
8. Reliability of service.

This paper discusses each of these points in connection with the experience we have had with the operation of a rectifier on the Chicago, North Shore and Milwaukee Railroad. The rectifier is rated at 1000 kw., 600 volts direct current and it is located on the section of the road as shown in Fig. 1. This section is fed also by synchronous converters of 1000-kw. and 1500-kw. rating as shown. This rectifier, made by the General Electric Company, is the first 600-volt machine made in this country which has been installed in actual service.

1. Chicago, North Shore and Milwaukee Railroad Co., Highwood, Ill.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Chicago, Ill., November 28-30, 1927.

EFFICIENCY

The efficiency of the rectifier was compared with that of five converter stations by taking measurements on each substation for five months. The results of the records are shown in the accompanying Table I. The efficiency is taken as the d-c. output divided by the a-c. input. The figures include the efficiency of power transformer and converter or rectifier. They do not

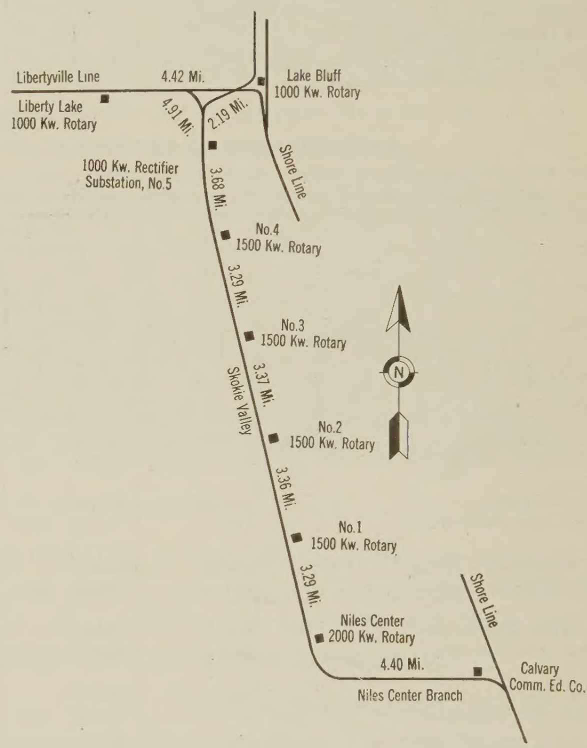


FIG. 1—SECTION OF RAILROAD FED BY RECTIFIER SUBSTATION

Location of synchronous converter substations also shown. Part of Chicago, North Shore & Milwaukee Railroad

include the power used for the operation of automatic devices and auxiliaries such as vacuum pump, motor-generator set, heaters in the rectifier station, nor the power used by auxiliaries and a-c. contactors in the converter stations.

I believe this comparison is fair. It was the best method I had of making a comparison in the short time available preparing this paper. Although not exactly correct, it shows a pronounced difference in the effi-

TABLE I

PERFORMANCE OF RECTIFIER AND SYNCHRONOUS CONVERTER SUBSTATIONS

The kw. and efficiency values do not include the power used for the operation of automatic devices and auxiliaries such as vacuum pump, water pump, motor-generator set and heaters in the rectifier station nor the power used for auxiliaries and a-c. contactors in the converter stations

Substations		Month of May 1927					Month of June 1927					Month of July 1927				
		Total kw-hr.	Total hr. run	Average hr. per day	Average kw-hr. per hour	Per cent efficiency	Total kw-hr.	Total hr. run	Average hr. per day	Average kw-hr. per hour	Per cent efficiency	Total kw-hr.	Total hr. run	Average hr. per day	Average kw-hr. per hour	Per cent efficiency
No. 1. substation..........	A-C. input	87300					86800					82200				
1500-kw. syn. converter...	D-C. output	62130	341	11	182	71.2	59024	300	10	130	68	57140	341	11	167	69.5
No. 2. substation..........	A-C.	43500					34200					34200				
1500-kw. syn. converter...	D-C.	30550	201	6.5	151	70.2	23214	180	6	128	67.8	25294	201	6.5	125	73.7
No. 3. substation..........	A-C.	69600					74400					78300				
1500-kw. syn. converter...	D-C.	53200	310	10	171	76.5	58200	330	11	176	78.3	60800	341	11	178	77.6
No. 4. substation..........	A-C.	125700					84300					95700				
1500-kw. syn. converter...	D-C.	97900	434	14	225	78	62400	315	10.5	197	74	73000	372	12	196	76.3
Liberty Lake.............	A-C.	115950					139950					146100				
1000-kw. syn. converter...	D-C.	83154	496	16	167	71.8	105844	660	22	160	75.6	104263	715	23	131	71.3
No. 5. substation..........	A-C.	89700					75900					79950				
1000-kw. mercury arc rectifier..................	D-C.	71952	403	13	178	80	62857	270	9	232	82.8	65747	387.5	12.5	170	82.2

TABLE I—CONT.

PERFORMANCE OF RECTIFIER AND SYNCHRONOUS CONVERTER SUBSTATIONS

The kw. and efficiency values do not include the power used for the operation of automatic devices and auxiliaries such as vacuum pump, water pump, motor-generator set and heaters in the rectifier station nor the power used for auxiliaries and a-c. contactors in the converter stations

Substations		Month of August 1927					Month of Sept. 1927							
		Total kw-hr.	Total hr. run	Average hr. per day	Average kw-hr. per hour	Per cent efficiency	Total kw-hr.	Total hr. run	Average hr. per day	Average kw-hr. per hour	Per cent efficiency	Average effic. of each substation, per cent	Average kw-hr. per hour	Grand average effic., per cent
No. 1 substation........................	A-C. input	95700					84300							
1500-kw. syn. converter.................	D-C. output	69770	403	13	173	72.9	61190	330	11	185	72.6	70.8	167.4	
No. 2 substation........................	A-C.	32100					50220							
1500-kw. syn. converter.................	D-C.	21133	186	6	113	65.8	33197	240	8	138	66.1	68.7	131	
No. 3 substation........................	A-C.	104400					95370							73.4
1500-kw. syn. converter.................	D-C.	83200	372	12	223	79.7	75300	360	12	209	78.9	78.2	191.5	
No. 4 substation........................	A-C.	84600					83040							
1500-kw. syn. converter.................	D-C.	65800	310	10	212	77.8	62300	285	9.5	218	75.	76.3	209.2	
Liberty Lake...........................	A-C.	119250					118740							
1000-kw. syn. converter.................	D-C.	88246	434	14	203	73.1	88731	525	17.5	169	74.7	73.3	166	
No. 5 substation........................	A-C.	70215					83460							
1000-kw. mercury arc. rectifier........	D-C	56721	341	11	166	80.7	67868	420	14	161	81.3	81.7	181.4	81.7

ciencies of the two types of equipment under nearly similar load conditions and very low load factor.

Very High Capacity to Absorb Momentary Overload

The ability of the rectifier to carry high momentary overloads is seen from the accompanying Fig. 2 which shows a graphic ammeter chart.

This chart which was taken 12 hr. after the unit was put in operation on a day of extremely heavy traffic. It shows load peaks much above the rating of the rectifier. There were no signs of being overloaded, an occasional opening of the high-speed circuit breaker which would reclose immediately, was the only trouble experienced in carrying this load.

Fig. 3 shows the typical load on the station. There are many very high load demands of short duration some of them well above the rated capacity of the rectifier.

On sustained overload we are not in position to give much information. Usually the load demand above the rectifier rating is of short duration, but there are unusual conditions on the railroad when a load of 175 or 185 per cent of the substation capacity may be

carried by any of these stations. The duration of this load is controlled by thermostats on the load-limiting resistors set to release this load in about six or seven min.

It is, however, possible to have a load above the rating of the equipment and below the 175 per cent overload relay setting for a much longer time than 7 min. A load of this kind would be without thermostatic control and might last indefinitely. It could be caused by traffic schedule disarrangement on account of trouble, extra passenger or freight service or a trolley wire on the ground at such a distance that the resistance of the feeders would limit the current.

Happenings of this nature are not unusual on a railroad and I believe that we have more than one time imposed on the rectifier an overload of much longer duration than we know. There are no recording instruments to show when this occurs. The rectifier does not show any signs of having been abused; momentary opening of the high-speed circuit breakers is the only indication that there must have been excessive load.

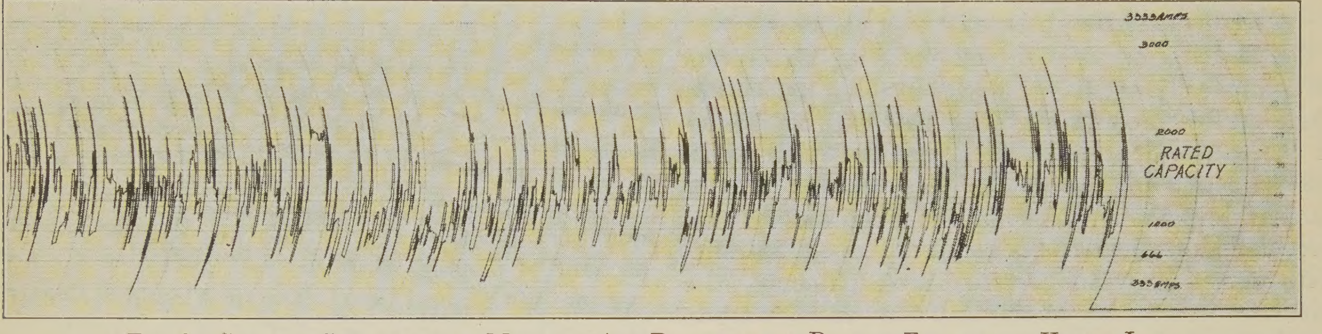


Fig. 2—Current Delivered by Mercury Arc Rectifier on Day of Extremely Heavy Load

Part of record of June 24, 1926 on Substation No. 5 of Chicago, North Shore and Milwaukee Railroad

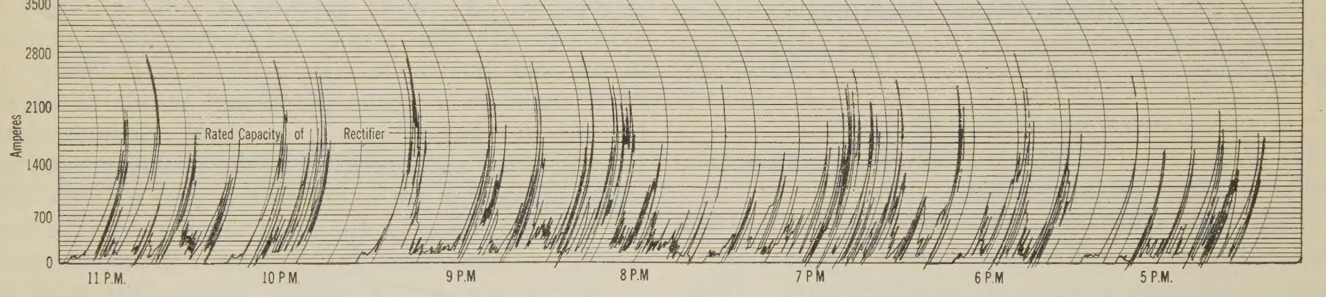


Fig. 3—Typical Load on the Rectifier Substation

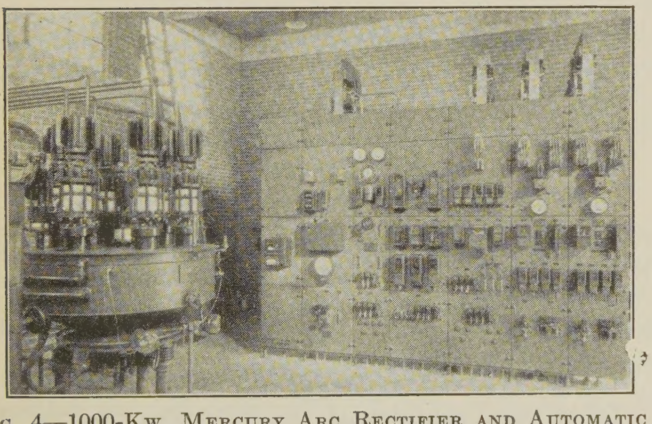


Fig. 4—1000-Kw. Mercury Arc Rectifier and Automatic Switchboard

Substation of Chicago, North Shore & Milwaukee Railroad

Insensitivity to Short Circuits

Our experience shows that the rectifier is not sensitive to short circuit. Repeated reclosing on a short circuit does not affect the rectifier. Under the same treatment a synchronous converter of the same capacity would be likely to flashover regardless of the protective devices, and in an automatic substation it would lock itself out and the station would be shut down until an inspector could put it back in service.

No Synchronizing

The fact that synchronizing is not necessary with the rectifier is quite important. In the automatic stations on our system only 4 to 6 sec. are required to connect a rectifier to the line. From 20 to 35 sec. are required to put a converter on the line. Therefore we can deliver a higher voltage to the train and trolley 16 to 29 sec. sooner with a rectifier.

Simple Operation and Minimum Attention

We must agree that the mercury arc rectifier requires less attention than the synchronous converter, and its operation is much simplier. There are no brushes, commutator nor slip-rings to take care of. There is no dust spreading over the equipment. These advantages are very much appreciated in automatic stations without attendance. The ventilation of the equipment and

building is also simplified as compared with converters, especially in unattended stations.

I do not want to create the impression that there are less devices involved in the mercury arc rectifier than there are in the converter station. On the contrary, with the rectifier more auxiliaries are used, such as arc-starting exciters, vacuum pump, water supply, temperature regulators, tank heaters, etc. While in our case some of these devices have caused a large number of shut-downs, the troubles were in the individual pieces of apparatus and they have been corrected. Those devices should not need much attention.

Noiseless Operation and No Vibration

The absence of vibration and noise in the mercury arc equipment makes it possible to install it in locations where the synchronous converter would not be allowed. In one converter installation it cost about $8000 for sound-proofing and ventilating the substation building, eliminating the noise to comply with the wishes of the surrounding residents. Such expense would not have been necessary with mercury arc equipment. Incidentally in addition to the first cost we have added ventilating equipment and extra building maintenance. Obviously, with the absence of vibration it is not necessary to install special foundations for the rectifier. It may be set on an ordinary floor. Ventilation becomes of minor or no importance, and in general a less expensive building is required.

Lower Maintenance Cost

We do not know at this time just what maintenance will be necessary on the rectifier.

From May 1926 to May 1927 this station was attended by an operator and the manufacturers of the rectifier kept a close watch on its performance. Being in a development or trial stage they took care of necessary maintenance. In addition, new developments which they made in other installations were applicable to this equipment and minor changes were made accordingly. Since May of this year this equipment has been in automatic operation without an operator. The maintenance required is very little, outside of the regular weekly inspections it has amounted only to applying a little oil. Like others we are watching this item with a great deal of interest. Our impression is that the maintenance will be very much less than that required for a converter although some manufacturers may have stretched this point a little too much. Time will tell.

Reliability of Service

The automatic rectifier station is as reliable, or more reliable, than the average 60-cycle synchronous converter station of the same capacity.

The record for this rectifier substation, commencing May 1926, when it was first started and put in service, all through a trial and adjusting stage until May 1927, when it was made automatic is as follows:

RECORD OF SHUT-DOWNS OF RECTIFIER

Cause of shut-down	No.	Total time, min.
High temperature of tanks	2	48
Exciter trouble	39	536
Driving chain and motor on water pump	13	315
Loose connection and bad control circuit	3	50
Vacuum-pump trouble, motor and oil pump	3	260
Flashover of anodes	6	819
Starting anodes sticking	5	602
Misc. unknown	12	1109
Total shut-downs	83	3739

Total time rectifier operated 337,140 min.

Shut-down by failure of	No. of times	Ave. time min.	Per cent of time of operation
Rectifier	25	58	0.435
Auxiliaries	58	39	0.674
All	83	45	1.109

Commenting on the foregoing data, it is of interest to note that the time the rectifier was out of service on account of troubles with the rectifier itself was 0.435 per cent of the total time. The time lost on account of the auxiliaries failures was 0.674 per cent of the total time.

The nature of the trouble with the auxiliaries is rather interesting. A larger amount of trouble might be expected with the rectifier on account of its newness in the field, but to have a small motor-generator set or a chain on a water pump and motor cause this bad record is out of place in our days. Engineers have been building and operating motor-generator sets and water pumps for years, but in this case we were after the big things but let the little things cause the most trouble. Fundamentally the record is good, the nature of the troubles is not serious. Since May 1927 the record as an automatic substation is as follows:

Failure in auxiliary	No. of shut-downs
Motor on one vacuum-pump burned out	1
Locked out after third reclosing of the oil circuit breaker within a definite time during storms	3
Locked out on account of broken spring on oil-switch mechanical latch	3
Locked out after third reclosing of the oil circuit breaker within a definite time, cause unknown	5
Fuse blown on operating transformer supplying power for the operation of devices	1
Total shut downs	13

Of all these shut-downs, the five lock-outs after the third closure of the oil switch could be questioned and possibly may have been caused by arc-back in the rectifier, or other troubles in the control which we have not detected. All the remaining troubles were not inherent with the rectifier, but were caused by other devices.

Our confidence in its reliability is such that we have

established a weekly inspection for this rectifier station, but we do not consider it advisable at present to leave a converter so long without inspection.

The record of the rectifier was compared with that of a synchronous converter of modern design and of the same capacity. This converter is located on another section of the railroad where the load conditions are about the same. It is protected from excessive loads by load-limiting resistors without high-speed circuit breakers. In this comparison I used none of the converters shown in Fig. 1 because these converters are of larger capacity than the rectifier and naturally they are more stable and would take a larger shock and carry more load without flashing over; nor have I used the converter at Liberty Lake, Fig. 1, as the momentary load demands on this station are less than they are on the rectifier.

The converter which I compared had 45,434 hr. of run on its record on May 1927 and had 34 flashovers causing as many shut-downs, representing 276 hr. out of service on account of flashovers. There was an average of 8.1 hr. out of service per shut-down as the majority of these flashovers, damaged commutator flash barriers, brushes, brush rigging and the insulation in other parts of the machine.

Since May 1927 to date this same converter flashed over 8 times and due to the many flashovers which this machine has had, extensive repairs had to be made on the commutator, rings and other insulation involving 150 hr. in one shut-down.

This record seems to indicate that the troubles with the rectifier itself probably will not be as serious as with the converter of the same capacity under similar load condition.

The writer has great confidence that the mercury arc rectifier is here to stay and predicts that 10 or 15 yrs. from now a large application supplementing the converter. The converter had its day, the rectifier's day is coming. It is true that the rectifier at present costs more than the converter of the same capacity and there is some misunderstanding as to its rating. But with an increasing number of installations and our cooperation, as operators, with the manufacturers, the development process will be speeded up and the production cost will naturally be reduced to a figure comparable with that of the converter.

The Hall High-Speed Recorder

BY E. M. TINGLEY[1]

Associate, A. I. E. E.

Synopsis.*—A new form of oscillograph for recording fault currents and their voltage disturbing effects in electric power systems is described. Representative records are analyzed and further applications of the instrument are suggested.*

Introduction

LIFE histories of electrical disturbances in the extensive 60-cycle, 12,000-volt systems of the Commonwealth Edison Company have been written during the last few months by the high-speed recorder developed by Chester I. Hall. The object of this paper is to describe the application of the device and the records obtained with only a limited reference to the details of its construction.

Description of Recorder

This instrument is a form of oscillograph for tracing continuously the maximum values of current and voltage during system fault conditions. Sturdy construction makes it suitable for application in generating stations and substations. It seems to be the only instrument yet developed for this class of service. Its performance lies between that of the standard oscillographs and the switchboard curve-drawing meters with speed-up attachments.

The measuring element or meter is of the saturated magnetic-vane type, having a natural period of vibration sufficiently high to attain full deflection always in the same direction in each half cycle of current measured, and the motion is practically dead beat. The envelop of the maximum deflections is therefore a measure of current or voltage.

Four meters, three for voltage and one for current, are inclosed in a light-tight case, and the records are made on a flat stationary, 11-in. by 14-in., superspeed photographic film.

The optical system consists of an automobile lamp with reflectors and lenses for concentrating light beams on the mirrors of the oscillating systems from which they are reflected to a movable plane mirror, which in turn reflects them to the photographic film. The plane mirror traverses the light beams across the film, giving a time scale to the records of 1 in. per sec. The traversing mirror is operated by a phonograph spring motor through suitable gearing.

A starting relay, dry batteries for the lamp, transformers for the current and voltage meters, and alarm and signal circuits complete the installation.

Under fault conditions, the relay connects the mea-

1. Commonwealth Edison Company.

Presented at the Regional Meeting of District No. 5, of the A. I. E. E., Chicago, Ill., Nov. 28-30, 1927.

suring elements to their transformers, lights the lamp, and starts the light-traversing mirror. The starting operations require 1/10 sec. or less. At the end of the record, which continues for 10 sec., the measuring elements are disconnected from their operating circuits, the lamp is extinguished, and the alarm is sounded.

Application

The Hall recorders as applied to the Commonwealth Edison system are installed in generating stations. They are started by fault currents to ground, and they measure this current and the three-phase voltages to ground. As faults invariably go to ground, the maximum information is obtained from a minimum number of recording elements.

The Commonwealth Edison 60-cycle, 12,000-volt system consists of four large separate systems, Crawford, Calumet, Fisk, and Northwest. Each unit system consists of a generating station with radial distribution cables to the substations. The neutral of one generator in each station is grounded through a 3-ohm resistor which limits ground-fault currents to about 2000 amperes. There are several hundred miles of 3-conductor cables in each 12,000-volt distribution system with only a few short overhead or open lines.

The generating stations are usually coupled only through their transformer lines so that a ground fault in one system does not cause ground current in another system. However, Fisk and Crawford are occasionally conductively coupled at 12,000 volts, and with this condition a fault causes neutral current at both generating stations.

The relays were first adjusted to trip with 125-amperes neutral current, but so many transient currents of undiscoverable origin operated the recorders without leaving a record that all the relays were readjusted to trip with 400 amperes. Transient currents were probably caused by synchronizing operations or the starting of transformers or motors.

The rather high condensive coupling to earth by the cables of the distribution systems may possibly be responsible for some of the neutral transients.

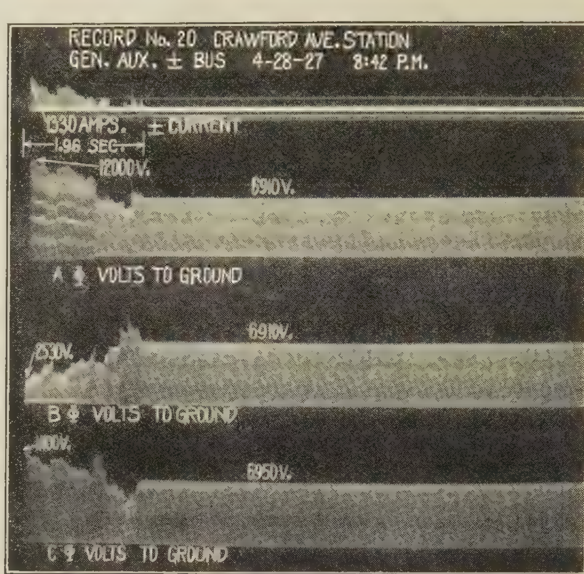
More than 100 records have been obtained, but only a few representative forms can be shown and described. They are necessarily a "behind-the-scenes" view of some of the accidents and failures incident to the operation of a great power system. However, very few of the failures recorded interrupted service.

The following paragraphs describe the faults recorded on the records shown in the corresponding illustrations.

Record No. 20, Crawford Station

Lightning on an overhead line started this fault. The *B*-phase was first affected after which the arc extended to the other phases in an irregular manner. The short period of zero neutral current may have been due either to the effect of a three-phase arc or to the momentary complete extinguishment of the arc. The opening of two circuit breakers, indications of which are lost in the arc irregularities, relieved the system of this fault.

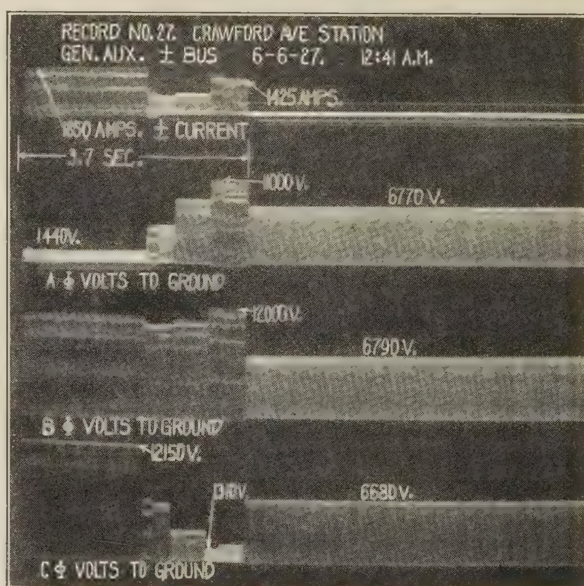
The excessive voltage disturbances shown are with respect to ground only. The delta or phase-to-phase voltage at the generating station is affected only slightly.



The disturbance pattern is characteristic of a long flaming arc in air.

Record No. 27, Crawford Station

This is an unusual case of two simultaneous single-phase failures to ground on separate cable lines. One failure by distortion of the system voltage with respect to ground precipitated the second failure and four



circuit-breaker openings were required to clear the two faults. Note that there are seven different steps in the neutral ground current. One of these is probably due to arc variations.

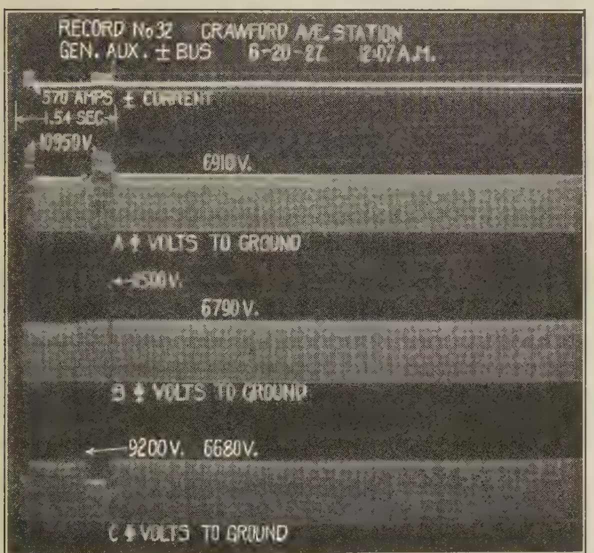
The first failure is on the A-phase and the second on C-phase. The abrupt increase of current at the beginning of the second fault is characteristic, as practically all records show that cable faults attain high current values very quickly.

The horizontal lines and patterns within the records are due to multiple reflections in the optical system. The vertical bands are caused by slight irregularities in the gears which drive the mirror that traverses the light beams.

A small allowance in the time scale is made for the starting time of the recorder.

Record No. 32, Crawford Station

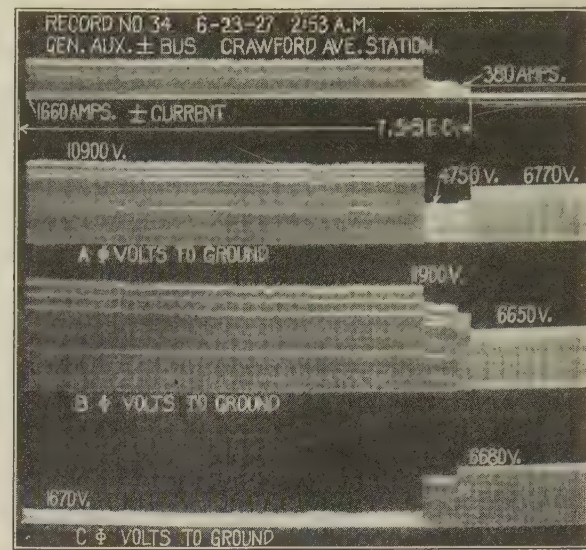
A three-phase cable fault produced this diagram and inspection of the burned cable indicated that the fault probably started between two phase conductors



and burned some time before going to ground, as the small time and small ground current indicated by the record do not account for the extent of cable burning. Zero value of neutral current during the first second of the record may be due either to a three-phase arc, or to the entire extinguishment of the arc. The fault was cleared by the operation of two oil circuit breakers, the effects of which are lost in the irregularities of the currents.

Record No. 34, Crawford Station

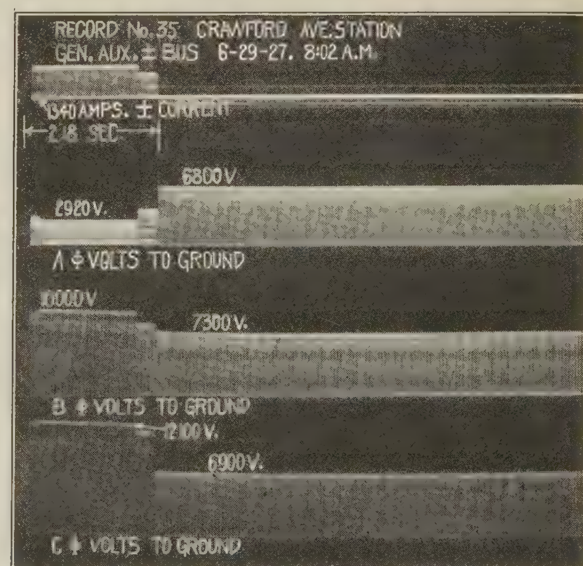
This record started with a C-phase cable fault to ground which extended to A-phase after 6.71 sec. The circuit-breaker relays were slow to respond to the ground-fault current, but the fault was quickly cleared by three circuit breakers after it developed to include another phase. As there are indicated only two steps in the neutral current reduction and three circuit



breakers operated, it seems that two breaker openings were simultaneous.

Record No. 35, Crawford Station

This is a usual fault to ground in one phase of a cable that was relieved by two circuit-breaker openings. The rounded corners in the current cut-off may indicate arcing within the circuit breaker. That the A-phase only is involved in the fault is shown by the reduction of the voltage of that phase to ground, and the increase of voltage on the other two-phases. This may be other-

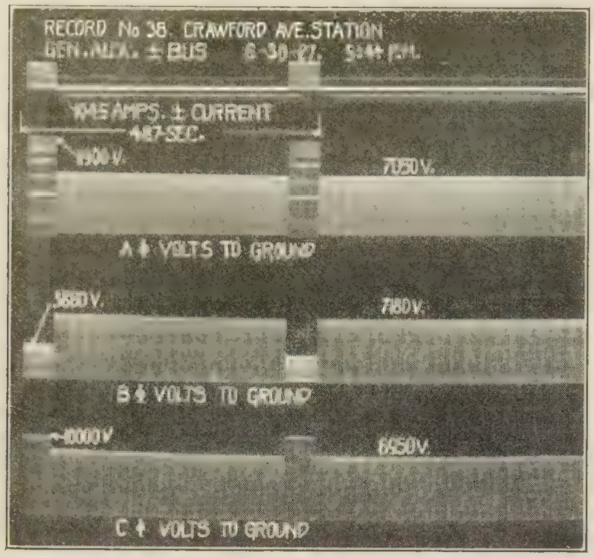


wise expressed as the displacement of the neutral point within the delta or as the tendency of the system voltage diagram to stand on one corner.

Record No. 38, Crawford Station

This record was made when system voltage was applied to a faulty cable. It is usual to make a ground test on a faulty cable by applying full system voltage on each phase singly by closing the disconnect and then

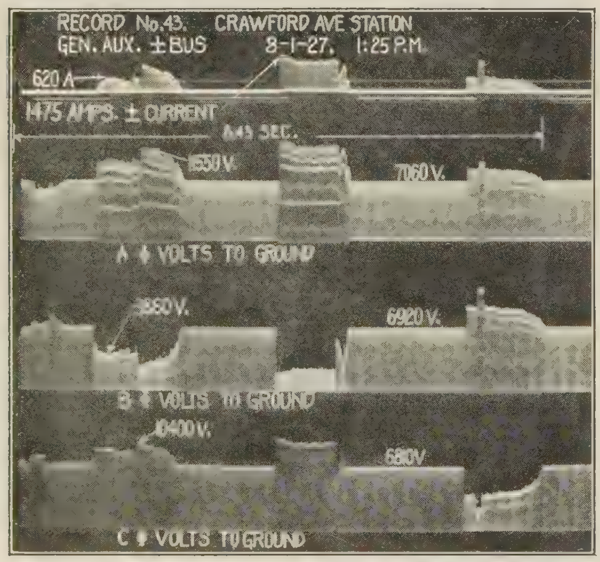
closing the oil circuit breaker. In this case, the circuit. breaker was closed twice on the faulty phase, B, possibly through the defective action of the circuit breaker Uniform closing and opening speeds in the circuit



breaker are indicated in both cases. This is an example of the way in which the Hall recorders furnish checks on the condition of apparatus and on its correct operation.

Record No. 43, Crawford Station

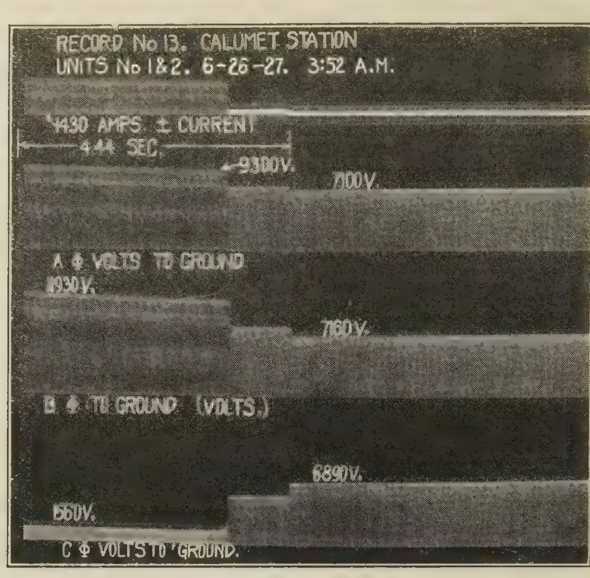
This trouble was caused by the leakage of brine on transformer bushings in an ice plant. Four bushings broke down. Two circuit-breaker operations were required to relieve this fault which may have extended beyond the 10-sec. limit of the recorder. The fault



seems to have started with small arcs on all three-phases and then ceased entirely, after which it concentrated on the B-phase and then on the C-phase. The irregularities in current and voltage are those of long arcs in air.

Record No. 13, Calumet Station

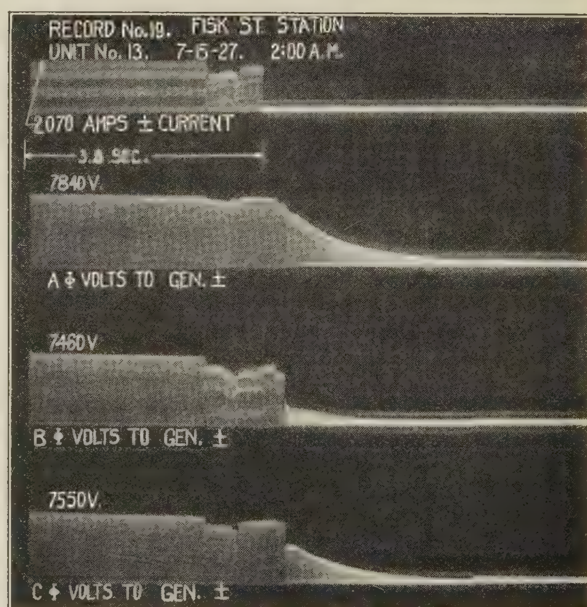
The steady current effect of the single-phase fault in the cable is again shown. The first and greatest reduction of fault current is caused by the opening of the circuit breaker at the generating station and the



final interruption is at the substation end of the cable. The fault current burned one cable conductor entirely in two. Small oscillations on B-phase voltage indicate that some synchronous apparatus may have been disturbed at the time the first breaker opened.

Record No. 19, Fisk Station

This most remarkable record of the series shows two cable failures and a generator winding failure, all to ground. In addition, there are three oil circuit breaker



operations and the opening of the generator-field circuit breaker, and the resultant dying down of the generator voltage. In this particular installation, the voltage is measured to the generator neutral and not to ground;

consequently, the voltage distortion registered is small.

It is possible to determine the time sequence of only a few of the events. The record started with a high neutral current due to B-phase cable fault, as the voltage on this phase is low. After about three seconds the C-phase was involved. The resulting voltage disturbance caused the generator winding to break down, which was quickly cleared through the action of the balanced differential relays. The relays also opened the generator-field circuit breaker and the generator voltage died down. The fault persisted on the B- and C-phases of the generator as indicated by the low voltage on these phases, and the higher voltage on the A-phase.

Starting Characteristics

In the generating stations as the recorders are started by neutral ground currents, a fault between phases does not start the recorder until shortly after it develops into a ground fault. Important parts of some faults are therefore lost. It has seemed impracticable to arrange a relay for starting on excess phase currents, as ground-fault currents are usually small and become lost in the load currents. Also, it is impracticable to start a recorder in generating stations by phase voltage reduction, as this is usually small. Starting on neutral ground current is the best compromise that can be effected.

It has been proposed to install recorders in some substations where the effects of voltage disturbances are important. A quick start may be made here on voltage reduction between phases, where it is important, but there will be no response to phase-to-ground distortions such as are measured at the generators. More complete information will be obtained through two sets of records, one at the generating station and one at the substation.

Records are frequently lost through the improper handling of the film holders and two separate sources of records furnish a good insurance against complete loss in important cases.

Use in Testing

Recently during oil circuit breaker testing, the recorders were found very valuable in measuring effects of the test currents on the system. The long time scale allowed the starting of the instruments through telephone orders just before the test currents were applied. There were, therefore, no lost intervals such as occur in automatic starting. Both generator and substation voltage disturbances were accurately measured. Such information is very valuable where synchronous apparatus or induction motors having no-voltage releases are liable to be shaken off the system due to momentary voltage reductions because of testing or fault currents.

General Comments Regarding Records

Records are not used to locate or identify system faults. This is better done by methods that were used before the recorders were available. Faults are located, inspected, and repaired long before the films are collected and developed. Usually there is a good agreement between the Hall records and inspection reports regarding the phases affected and other details so far as they may be interpreted. Normal faults to ground in cables and resulting breaker operations are rather uniform in performance. Departure from a normal characteristic calls for explanation regarding circuit-breaker relay operation, and in this way the records are of great value in checking the operating condition of such apparatus.

The effectiveness of the isolated-phase principle in generator station design has been fully demonstrated and recorded. On one occasion a single-phase arc to ground on the Crawford bus burned for 2¼ min. without affecting service. The first four seconds of fault produced a record at Fisk Street through a temporary 12,000-volt tie. The remainder was obtained from the speed-up charts.

THE NEW HEINRICH HERTZ INSTITUTE
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The extraordinary rapid development in all branches of technical electricity, especially in communication, together with the unfavorable conditions of the post-war period, has left the scientific research work in this field far in the rear. The danger in this condition requires no discussion; in the final analysis, every advance depends on the results of scientific research; without it, a sound development of technology is not possible in the long run. In order to promote research on the subject of electric and acoustic oscillations, in support of a suggestion made by State Secretary Dr. Bredow, the German Post Office, the Prussian Minister of Science, Art and Public Education, the Reichsrundfunk-Gesellschaft, the Technical High School of Berlin, the large firms in the electrical industry, and the Verband Deutscher Elektrotechniker organized for oscillation research. The group has the task of inaugurating and maintaining a research institute at the Technical High School of Berlin, to be known as the "Heinrich Hertz Institut für Schwingungsforschung" in honor of the discoverer of the electric waves. It will have as its head, the former president of the Telegraphentechnischen Reichsamt, Prof. Dr. Engr. E. H. K. W. Wagner. At the same time President Wagner will assume the professorship for oscillations, just formed at the Technical High School of Berlin.

Commercial Messages over the oceans interfere very little with land broadcasting now because of the passage of the old-style spark transmitters which once were scattered up and down the coasts, especially from Bar Harbor, Me. down to Washington, D. C. These usually operated on a wave length of about 450 meters. Today continuous-wave, vacuum-tube transmitters are used almost exclusively for transoceanic and ship-to-shore communication and the wavelengths are usually between 1800 and 2000 meters, which lifts commercial radio out of the zone of popular broadcasting.—*Elect. Zeit.*, Sept. 15.

The Chicago Regional Power System

BY E. C. WILLIAMS[1]
Member, A. I. E. E.

Synopsis.—*This paper is a general description of the interconnected power systems in the region surrounding and including Chicago as a center. The electrical energy generated in this region in 1926 was over 4,000,000,000 kw-hr. and the combined generating capacity of the three largest companies was 1,340,000 kw. The paper outlines important features of major stations and transmission and distribution systems and gives plans for the future developments. It also explains the contract for interchange of energy among the three largest companies.*

* * * * *

THE design of any electricity supply system should be coordinated with the geographical, industrial and social character of the community which it serves. The electricity supply systems of the Chicago territory are in a rather unusual position in this respect because of the potential resources, both industrial and commercial, of the territory served. Chicago, due to its location, has been since the beginning in an excellent position to command an enormous growth. Being near the center of a great agricultural district with coal, ore, lime-stone and other deposits close at hand, with excellent transportation facilities both by rail and water, it is not surprising that it has grown from a village of 4500 people in 1840 to a city with a population of 2,700,000 at the time of the last official census and now estimated at 3,700,000. The Chicago Regional Planning Association estimates that by 1930 there will be a population of 4,891,600 within a radius of approximately 50 mi. of Chicago.

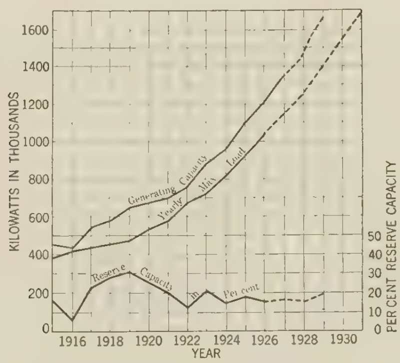

Fig. 1—Generating Capacity and Maximum Load in the Chicago Region

This industrial and commercial activity has created a demand for electric power which has been met by what has been called "the greatest pool of power in the world." According to the U. S. Geological Survey 73,791,064,000 kw-hr. of electrical energy were generated in 1926 by utility companies in the United States and 4,128,455,000 kw-hr. or 5.6 per cent were produced in the Chicago region.

The principal companies serving this area are as follows: Commonwealth Edison Company, Public Service Company of Northern Illinois, Northern Indiana Public Service Company, and Illinois Power & Light Corporation. The combined load of the three larger Companies, namely, the Commonwealth Edison Company, the Public Service Company of Northern Illinois and the Northern Indiana Public Service Company all of which are operated by the same interests has shown a growth in the last decade as shown in Fig. 1, the maximum load being below 400,000 kw. at the beginning of 1916 and being slightly above 1,000,000 kw. at the peak load period in 1926.

The stations of these three companies with their present capacities are shown in the following tabulation:

PRESENT GENERATING STATION CAPACITIES IN THE CHICAGO REGION

Commonwealth Edison Company		
Crawford Avenue Station	324,000 kw.	
Calumet Station	187,500	
Fisk Street Station	230,000	
Northwest Station	165,000	
Quarry Street Station	84,000	
Miscellaneous	65,060	
		1,055,560 kw.
Public Service Company of Northern Illinois		
Waukegan	110,000 kw.	
Joliet	50,000	
Blue Island	43,000	
Miscellaneous	34,790	
		237,790 kw.
Northern Indiana Public Service Company		
East Chicago	26,400 kw.	
Miscellaneous	20,425	
		46,825 kw.
GRAND TOTAL		1,340,175 kw.

GENERATING CAPACITIES TO BE ADDED IN THE NEXT TWO YEARS

1928	Crawford Avenue	100,000 kw.
1928	Powerton (Partly for use of Chicago Region)	52,000 kw.
1929	State Line	200,000 kw.

The Crawford Avenue Station with a capacity of 324,000 kw. is at present the largest station in the region and is capable of being developed to perhaps three quarters of a million kilowatts provided there is a certainty as to the amount of condensing water that can be depended upon from the Drainage Canal. A view of the turbine room of this station is shown in Fig. 2.

Another large generating station is the Calumet

1. Electrical Engineer, Public Service Company of Northern Illinois.

Presented at the Regional Meeting of District No. 5, of the A. I. E. E., Chicago, Ill., Nov. 28-30, 1927.

Station located on the Calumet River having a capacity of 187,500 kw. which is already utilizing about all available water in the Calumet River and has consequently reached its ultimate capacity. Other large stations in Chicago are the Northwest Station, the Fisk Street Station and the Quarry Street Station which are older stations and on account of water conditions and property limitations can only be increased in size by the replacement of present units with more efficient units of larger size.

The main outlying stations are at Waukegan and Joliet with present capacities of 110,000 kw. and 50,000 kw. respectively. The site at Waukegan is capable of development to approximately 1,000,000 kw. The site at Joliet is capable of similar development providing the condensing water available from the Drainage Canal is not limited as mentioned in connection with the Crawford Avenue Station.

As to future generating stations which will furnish energy to the Chicago region two large ones are already

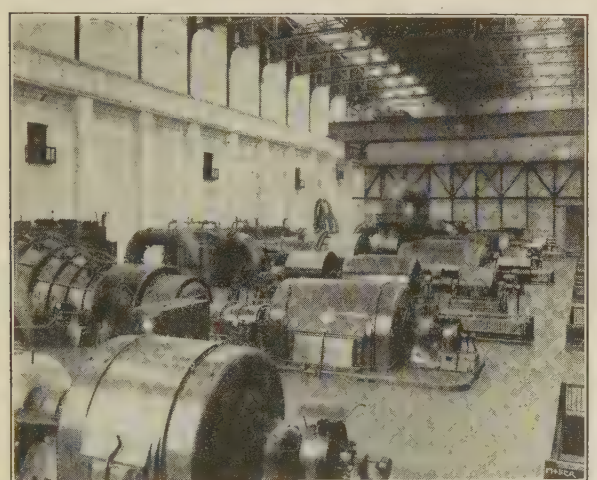

FIG. 2—TURBINE ROOM, CRAWFORD AVENUE STATION

under construction, namely the Powerton Station located southwest of Peoria near Pekin on the Illinois River and the State Line Station on Lake Michigan at the Illinois-Indiana State Line. Property has been acquired in Michigan City and also at a location southwest of Chicago on the Drainage Canal for the construction of future generating stations but it has not been definitely announced when construction will begin at either of these points. The Powerton Station is rather unique in that it is jointly owned by four companies which are the Central Illinois Public Service Company, the Illinois Power and Light Corporation, the Public Service Company of Northern Illinois and the Commonwealth Edison Company. These companies have pooled their comparatively small requirements in the immediate vicinity and are erecting this modern efficient station. The first unit with a capacity of 52,000 kw. is scheduled for completion during the summer of 1928. In connection with this project a 132,000-volt transmission line is now being built from Joliet through Oglesby and Kewanee to the Powerton Station for interconnection with the Chicago pool.

With regard to the State Line Station, the tract of land procured is adequate and plans are being made for a station with an ultimate capacity of a million kilowatts or more. This station is to be owned jointly by the Commonwealth Edison Company, the Public Service Company of Northern Illinois, the Northern Indiana Public Service Company and the Middle West

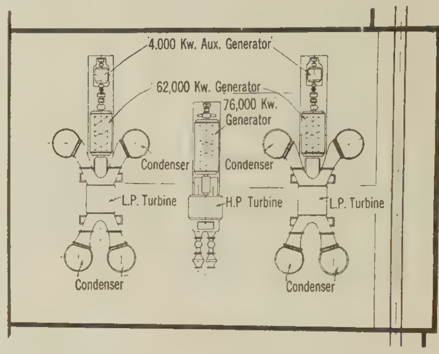

FIG. 3—UNIT NO. 1, STATE LINE POWER STATION

Utilities Company. The first unit, scheduled for completion in 1929, is to have a capacity of 200,000 kw. and will consist of three turbo generator sets each having a capacity of approximately one-third of the total arranged as shown in Fig. 3. Steam at 650 lb. pressure is admitted to a single high pressure turbine which exhausts into two identical low-pressure turbines each taking half of this exhaust steam.

In the design of this unit, means are provided where-

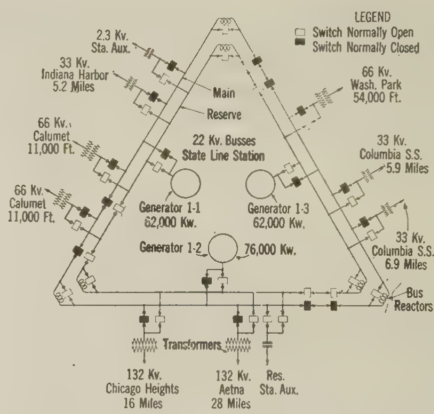

FIG. 4—BUS AND FEEDER CONNECTIONS, 1929 STATE LINE STATION

by any one of the three turbines may be taken out of service and the other two continued in operation thus overcoming the common objection from an operating standpoint of such a large capacity being contained in one unit. At present five such units of 200,000 kw. each are planned for this station with suitable transmission facilities for carrying away the energy. Contrast with these units, the 30,000-kw. units which were installed at the Calumet Station as late as 1921, which

were then the largest ever built for this territory.

The electrical installation also is rather unusual in that the generator bus will be completely out of doors and entirely enclosed by metal so that no physical contact can be made with any live parts. Fig. 4 shows the schematic arrangement of the bus which is a double ring bus divided into three sections, one generator supplying each section with suitable reactors and oil circuit breakers between sections. It is so laid out that as future generators are added one additional bus section will be placed in the ring for each additional generator. The generator voltage and consequently the bus voltage for this station is to be 22,000-volts which is somewhat higher than ordinary practise. The station is designed purely as a generating station and the energy will all be transmitted away in large quantities either at 33,000, 66,000 or 132,000 volts. No line busses are provided, transformers being installed integral with each individual line.

Another unusual electrical installation is to be found at Waukegan in the 12,000-volt "iron-clad" switchgear used in connection with the recently installed 50,000-kw. (58,825 kv-a.) unit. Although equipment of this type has previously been used in connection with lower voltage bus work at several substations in the Public Service Company territory, the Waukegan installation is the first used in a generating station in this country in connection with such a large capacity. The largest switches are rated at 1,500,000 kv-a. interrupting capacity and 3000 ampere carrying capacity. This

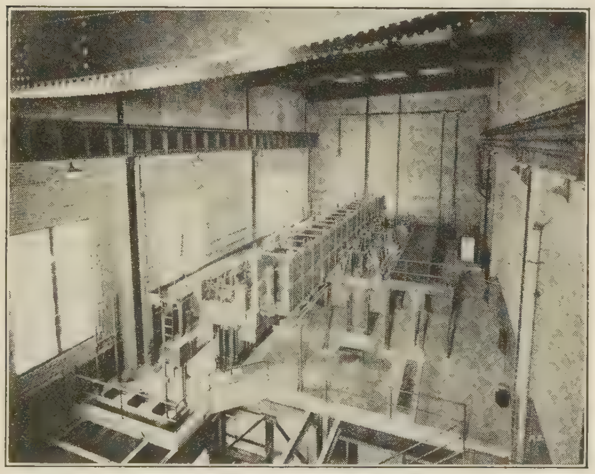

Fig. 5—Iron-Clad Switchgear on Generating Bus, Waukegan Station

installation which is indoors completely encloses in metal all of the bus work and switching equipment and thus reduces the hazard to operators in coming in contact with live parts as well as providing several other important advantages. This apparatus is very compact thus simplifying the building requirements both at the time of installation and at times when it is necessary to make additions or increase capacity. It is shipped in units or groups of units with practically all wiring, taping and adjustments completed in the factory where workmanship and labor costs are naturally more favorable than in the field. Fig. 5 shows a view of this equipment.

In general this matter of switching equipment is becoming quite serious especially as to interrupting capacities. It would seem that the development of

Fig. 6—Transmission System in Chicago Region as Proposed for 1928

high interrupting capacity switch gear has not kept pace with the growth of the business and consequently the requirements of the supply companies. The result has been that the supply companies have quite often been forced to make costly changes in structures as well as retire comparatively new equipment due to radical changes in design on the part of the manufacturers or unsatisfactory performance of equipment.

The transmission system in the Chicago region has had a very interesting development. Practically all of the stations have been interconnected. Within Chicago the system has developed from one 2250-volt transmission line in 1897 to the network of 12-kv. and 66-kv. underground cable of today. The outlying stations are either connected with each other or with the Chicago stations by means of a 132-kv. net-work with an auxiliary 33-kv. system. Fig. 6 shows the system as it will appear in 1928. It is to be noted that superpower interconnections have already been made with neighboring companies on practically all sides.

The transmission of large blocks of power through densely populated areas will soon require the extensive use of high-voltage underground cables. A move in this direction is to be noted in the six mi. of 132-kv. underground line connecting the Northwest Station in Chicago with the overhead transmission line from Waukegan at the city limits. This line consists of three single-conductor, hollow-core, oil-filled cables with a capacity of 90,000 kv-a. and has been in satisfactory operation since June of this year.

In this same connection there is still room for improvement in the design of overhead transmission lines,

especially in regard to mitigating the effects of lightning. Considerable progress in this respect however has been made during the last few years by the use of ground wires, arc-controlling devices and the lowering of the plane of the conductors. The following tabulation summarizes the experience with ground wires in this territory:

EFFECT OF GROUND WIRE ON 132-KV. OVERHEAD LINE INTERRUPTIONS CAUSED BY LIGHTNING

Line		Interruptions			
No. Location	Length miles	1924	1925	1926	1927
1. Waukegan—Niles Center..	27.5	28*	20*	14*	0‡
2. Waukegan—Northwest Station................	31.1				1*¶
3. Waukegan—Kenosha......	20.7				0‡
4. Joliet—Chicago Heights...	29.8		9	29	1‡
5. Chicago Heights—108th St	14.4		7¶	7¶	6¶
6. 108th Street—Aetna......	26.7		0†‡	0†‡	1†‡
TOTAL..................	150.2	28	36	50	9

*Equipped with arcing-rings.
†13.8 mi. equipped with arcing rings.
‡Ground wire installed over circuit.
¶Ground wire installed over circuit on opposite side of tower.

The improvement brought about by the use of ground wires is conspicuously evidenced in the case of lines No. 1 and No. 4 where the ground wires were installed after some experience without them.

I wish now to refer to the "interchange energy contract" between the Commonwealth Edison Company, the Public Service Company of Northern Illinois, and the Northern Indiana Public Service Company by means of which an equitable interchange of energy and capacity is obtained. The capacity of all three companies is placed in a so-called "power pool" from which each company may draw in order to supply its load. The principal purpose of the arrangement is to enable the entire load of the three companies to be carried by the most efficient generators regardless of their ownership, leaving the less efficient to carry the peaks and to act as reserve. The energy is paid for by each consuming company at various rates depending upon the stations from which the energy is supplied. The investment charges are taken care of on a basis of demand and capacity illustrated by the following typical example. The figures given in the following tabulation show the generating capacity and previous maximum load for each company as of December 31st, 1926, one of the monthly billing dates. The total generating capacity of 1,199,500 kw. is allotted to the three companies in the ratio of their previous individual maximum demands shown in the second column.

	Generating capacity 12-31-26	Previous maximum demand 12-31-26	Demand at time of system max. 12-15-26
Commonwealth Edison Co.	965,000 kw.	864,300 kw.	864,300 kw.
Public Service Co. of Nor. Ill..................	187,800	139,800	135,600
Nor. Ind. Public Service Co.	46,700	43,600	40,200
TOTAL.............	1,199,500 kw.	1,047,700 kw.	1,040,100 kw.

The company actually owning generating capacity, shown in the first column, in excess of its allotment receives the carrying charge on this excess from the other two companies which own less than their allotments. A limit of 20 per cent reserve on the total system is set up beyond which no credit is given.

I now wish to refer briefly to studies of the transmission network which are being made in the Chicago region. A plan has been adopted wherein the entire region including the City of Chicago has been divided into areas for distribution purposes. All the energy for each of these areas is to be supplied from one source. This source may be a generating station or a large or major distribution center receiving its supply over either 66,000 or 132,000-volt transmission lines. The energy is to be distributed at 33,000 or 12,000 volts from this main source to the various substations in the area for re-distribution. The substations in one area will not, in general, be connected to those of another

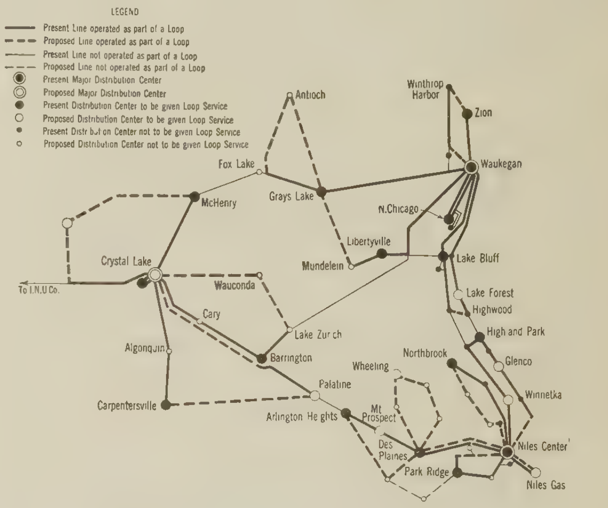

FIG. 7—PROPOSED 33,000-VOLT AREA TRANSMISSION SYSTEMS
Public Service Company of Northern Illinois, North Part of Territory

area although some emergency ties may be needed which will normally be operated open. With this system, the relay problem will be materially simplified and trouble may be more easily segregated than with the system in use at present wherein the various substations are connected to several sources. The duty on oil circuit breakers will also be considerably reduced. Fig. 7 shows the proposed scheme applied to a part of the territory of the Public Service Company of Northern Illinois. The high-voltage transmission lines supplying the major distribution centers are not shown. The groups of radiating loops from the major distribution centers conspicuously define the respective areas.

Fig. 6 shows two such major distribution centers planned for Chicago located at Washington Park and Humboldt Park to be supplied at 66,000 volts and scheduled for completion in 1928 and 1929 respectively. They are in addition to those already established at the

various Chicago generating stations. By 1928 the area surrounding Chicago will have several similar major distribution centers other than the generating stations, the most important of which will be located at Niles Center, Bellwood, Chicago Heights, Aetna, Michigan City, Oglesby and Kewanee.

Transportation in the Chicago Region accounts for a considerable part of the demand for electrical energy. Of the 1,040,100 kw. total system demand which occurred December 15th of last year nearly 350,000 kw. was supplied to the electric railways in and around Chicago. The first and only steam road in this region to electrify is the Illinois Central Railroad which completed the electrification of its suburban service in June of last year. This customer's maximum demand to date has been 22,864 kw. The railroad operates its cars at 1500-volts direct current supplied by seven substations, five of which are owned by the Commonwealth Edison Company and two by the Public Service Company of Northern Illinois. The conversion to direct current is accomplished in some cases by mercury arc rectifiers and in others by units of two 750-volt rotary converters in series. Fig. 8 shows the Vollmer Road Substation at Flossmoor, installed by the Public Service Company of Northern Illinois for supplying this railroad and the light and power business in that vicinity. This particular substation was thought of interest inasmuch as it is located in a residential territory and in order to harmonize with the developments in that region a building of Spanish design which should not detract from the general surroundings was erected. The first impression might be that such a design is expensive but if the architect is ingenious in

Fig. 8—Vollmer Road Substation

the use of materials this need not be so. In fact the cost per cubic foot of content of this particular substation, was practically the same as that of another substation erected at the same time following the ordinary type of construction.

Fig. 9 shows the Glen Ellyn Substation supplying direct current to the Chicago, Aurora & Elgin Railroad where harmonizing architecture was used again.

In this presentation I have tried to point out the problems existing in this region with the idea of bringing them to the attention of engineers generally as these problems are not peculiar to this locality but are being encountered in similar metropolitan areas. Engineers connected with power developments in such regions should be on the alert to so carry on system design that future demands may be met at reasonable cost and with a minimum of obsolescence.

It may be regarded by some as highly optimistic but

Fig. 9—Glen Ellyn Substation

it is not inconceivable that sometime in the future the dictates of our customers may make intolerable the voltage dips and momentary interruptions due to lightning discharges and emergencies, the elimination of which we are prone to regard as insurmountable. It is to such problems that I commend the energy of the engineer for scientific study in order that the quality of service we render may continue to improve and that our system may be competent to meet the requirements of the public which are rightfully becoming more exacting year by year.

WEIGHING BY RADIO

One of the latest applications of the radio principle appears in a weighing machine developed by the laboratory staff of a large New England producer of pulp and paper. This unique device automatically weighs any material, such as paper, rubber, chewing gum and coated fabrics, passing through the mechanism in continuous web form. This is accomplished at full machine speed without touching the web of material at any point.

The principles underlying this unusual development are those of the tuned radio circuit. The web of material passes between two parallel metal plates which act as a condenser in the receiving circuit. Variations in the weight of the web change the capacity of the condenser and affect the response of the circuit to a wave of controlled frequency. These variations are shown on a meter connected in the circuit and may be used to operate machine controls by suitable relays. The machine is of great service in maintaining uniformity in the weighing of paper and an adaptation of the device may be used to register the moisture content of the paper.

The Vacuum Tube Rectifier

Oscillographic and Vacuum Tube Voltmeter Study of its Application to B-Voltage Supply for Radio Receivers

BY JOHN H. KUHLMANN[1]
Member, A. I. E. E.
and
JAMES P. BARTON[2]
Enrolled Student

Synopsis.—*This paper covers investigations made in undertaking the design of a rectifier for use as the B power supply for radio receivers. It determines the most satisfactory type of filter circuit and the appropriate values of inductance and capacitance to give a d-c. output delivered with the least practicable voltage drop and having no fluctuations of sufficient magnitude to interfere with the proper operation of the set. A vacuum-tube peak voltmeter used to detect very small fluctuations is described.*

THE object of this investigation was to determine a good method of design for a vacuum-tube rectifier for converting alternating current into direct current equivalent to that obtained from a battery. The d-c. output should be such that it can be used to properly operate a radio receiving set and loudspeaker without introducing any interference or modulation from the a-c. source. The study of the the eliminator was prompted by the lack of engineering literature[3] on the subject and by the desire of the writers to more fully understand the proper design, the characteristics, and the limitation of the device.

The study is divided into several sections.

1. The rectifier vacuum tubes.
2. Oscillographic study of the action of inductance and capacity, (alone and in combinations), upon the rectified wave form.
3. Vacuum tube peak voltmeter study of the small ripple in the load current and its elimination by use of two section filters.
4. Calculation of per cent voltage fluctuation.
5. Conclusions.

The eliminator to be investigated consists of three distinct units,

1. The rectifier proper
2. The filter
3. The load resistance for dividing the load voltage.

The units which make up the general circuits under study are shown in Fig. 1. In Fig. 2 is shown the completed eliminator and its parts as used in this study.

SECTION 1. THE RECTIFIER VACUUM TUBES

The vacuum tubes used for the rectifier were the obsolete power tubes, UV-202, being the only tubes available at the time. Three tubes were tested; their plate current—voltage and plate current—resistance curves are given in Figs. 3 and 4, respectively.

From the plate voltage—current curves in Fig. 3 it is seen that the tubes T_1 and T_3 saturate at a much lower current density than T_2, which was an unused tube. T_1 and T_3 had both been used as oscillators; T_3 used longer than T_1. These curves show that if the rectifier is required to give a peak current of over 100 milli-

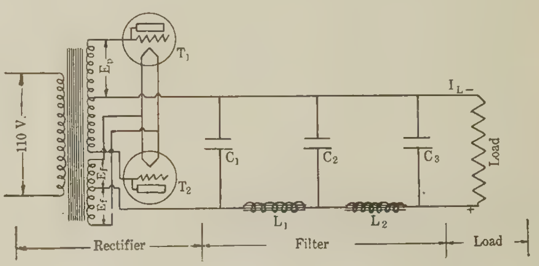

FIG. 1—CIRCUIT DIAGRAM OF EXPERIMENTAL VACUUM TUBE RECTIFIER

Rectifier:
E_p = 300 volts effective from center-tapped transformers
E_f = 3.75 volts effective from center-tapped transformer
$T_1 = T_2 = U\ V$ 202 5-watt power tubes with grid connected to plate
Filter:
C_1, C_2, C_3 are 500-volt condensers. Several values of capacity were used in the experiment
L_1 and L_2 are similar iron-cored inductances each having an inductance of about 30 henrys for the normal d-c. excitation. The cores are in two laminated sections, each L-shaped; butt joints are used giving small variable air-gaps. Each coil contains about 6200 turns with an average resistance of 645 ohms
Load:
Low-inductance, wire-wound variable resistance units of ample current capacity. Resistors for final set are wound on flat strips of bakelite and are of fixed value. Several values of resistance were used in the experiments

amperes, the rectified current wave will be flat topped.

The plate current—resistance curves, (Fig. 4), were obtained to show the variation of plate resistance with the rectified current. These curves are desirable in order to match tubes and thus obtain equal amplitudes in both halves of the rectified wave.

In the oscillograms, Fig. 2B, V_1 and V_2 show the current wave forms as per T_1 and T_2, and V_3 gives the resulting current I_L, in the resistance load of 8000 ohms. The values of V_1, V_2 and V_3 were taken simultaneously. The circuit diagram is shown in Fig. 2A.

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1. Assistant Professor of Electrical Design, University of Minnesota.

2. Minneapolis, Minnesota.

3. See "Theoretical and Practical Aspects of Low Voltage Rectifier Design When Employing the Three-Electrode Vacuum Tube" by R. D. Duncan, Jr., *Radio Review*, Vol. III, 1922, pp. 59-71 and pp. 114-124. "The Production of Constant High Potential With Moderate Power Capacity" by A. W. Hull, *G. E. Review*, Vol. 19, 1916, pp. 173. "The Thermionic Vacuum Tube" by Van Der Bijl, Chapter VI, McGraw Hill, New York. "Alternating Current Rectification" by L. B. W. Jolley, Chapter X, John Wiley & Sons, New York.

Presented at Regional Meeting of District No. 5 of the A. I. E. E., Chicago, Ill., Nov. 28-30, 1927.

The wave forms V_1 and V_5, Fig. 2B, show the resulting current in the load and the 60-cycle e. m. f. applied to the rectifier, respectively. The oscillograms show that the rectified current is in phase with the applied voltage. This is to be expected, as there is practically no reactance in the load circuit.

The half wave rectifier gives a load current wave form as shown in Fig. 2B by V_1 or V_2.

The current wave forms, instead of the voltage,

Fig. 2—Assembled Rectifier with Filter

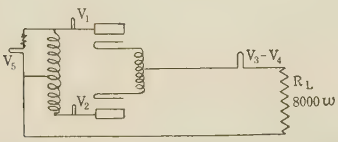

Fig. 2a—Circuit Diagram of Rectifier Without Filter

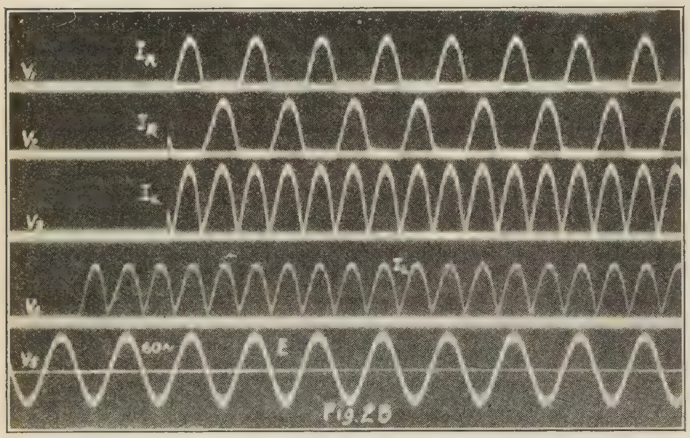

Fig. 2b—Oscillograms for Rectifier Circuit Fig. 2a

V_1 and V_2 are individual tube output currents. V_3 and V_4 are load current for full-wave rectifier. V_5 is 60-cycle applied voltage

were observed throughout this study because the current consumed by the voltage element of the oscillograph is a large portion of the total rectified current and therefore would disturb the circuit and current conditions to be studied.

Section 2. Oscillographic Study of the Action of Inductance and Capacity Alone and in Combination Upon the Rectified Wave Form

The Effect of Capacity on the Load Current Wave Form. The addition of capacity across the load resistance of a rectifier, as in Fig. 3A, reduces the ripple in the load current. The operation of the condenser may be explained as follows: When the voltage is applied to the rectifier, the condenser takes a charge and continues

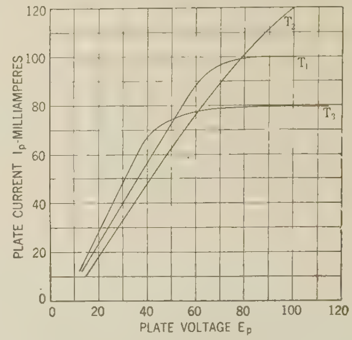

Fig. 3—Plate Current—Voltage Characteristic of Three $U\,V$-202 Vacuum Tubes

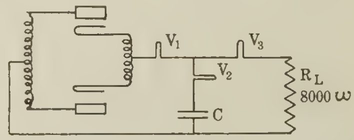

Fig. 3a—Circuit Diagram of Rectifier with Capacity Shunted Across Load Resistance

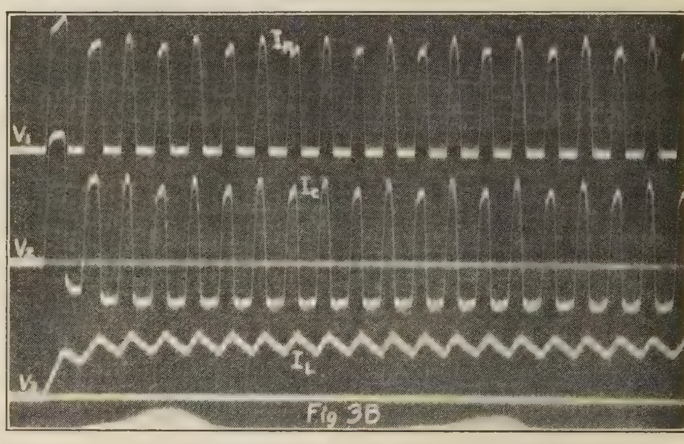

Fig. 3b—Oscillograms for Rectifier Circuit Fig. 3a

V_1 is rectifier current. V_2 is condenser current. V_3 is load current with 2.13 μ f. shunt capacity

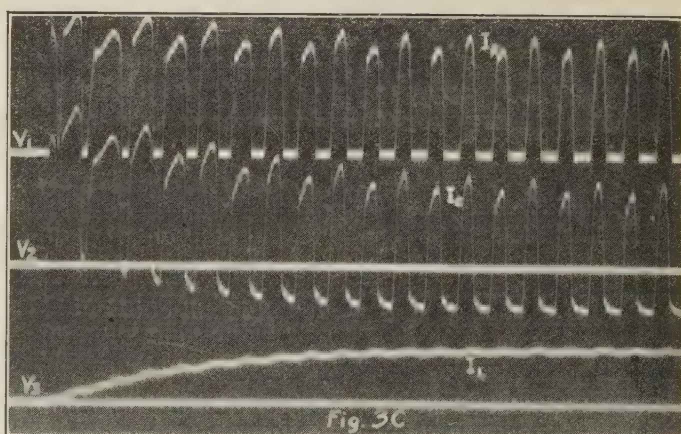

Fig. 3c—Oscillograms for Rectifier Circuit Fig. 3a

V_1 is rectifier current. V_2 is condenser current. V_3 is load current with 12.13 μ f. shunt capacity

charging until the rectifier voltage reaches its maximum value. As soon as the rectifier voltage begins to decrease, the condenser begins to discharge and in so doing, builds up a voltage across the tubes which opposes the applied voltage. The rectifier current wave, therefore, takes the shape shown by V_1, Fig. 3B, instead of that shown by V_3, Fig. 2B. The condenser continues to discharge until the decreasing condenser

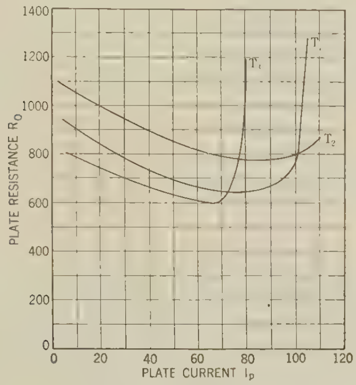

FIG. 4—PLATE CURRENT—RESISTANCE CHARACTERISTIC OF *U V*-202 VACUUM TUBES

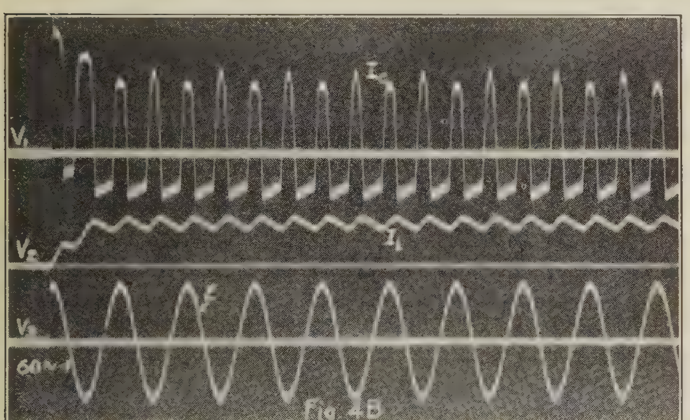

FIG. 4B—OSCILLOGRAMS FOR RECTIFIER CIRCUIT FIG. 3A

V_1 is condenser current. V_2 is load current with 2.13 μ f. shunt capacity. V_3 is 60-cycle applied voltage

voltage becomes equal to the increasing rectifier voltage. The load current pulsations are of much smaller amplitude for the circuit shown in Fig. 3A than for the circuit shown in Fig. 2A, because the condenser discharges through the load resistance and supplies the load current during the time the rectifier voltage is passing through zero. The condenser discharges through the load resistance in accordance with the law for the discharge of a condenser through a resistance; that is,

$$i = \frac{E}{R} \epsilon^{-\frac{T}{RC}}$$

From the above discussion, it appears that it should be possible to reduce the load current ripple by increasing the time of discharge of the condenser. For a circuit such as shown in Fig. 3A, the time constant,

$$T = R C$$

Since the load resistance is fixed, the time constant can only be increased by increasing the capacity. Fig. 3B shows the load current when the shunt capacity is 2.13 microfarads and Fig. 3C shows the load current for a shunt capacity of 12.13 microfarads. The oscillograms show that the ripples in the load current are very much less for a shunt capacity of 12.13 microfarads than for a capacity of 2.13 microfarads.

In Fig. 4B, the relation between the condenser current V_1, the load current V_2, and the impressed 60-cycle

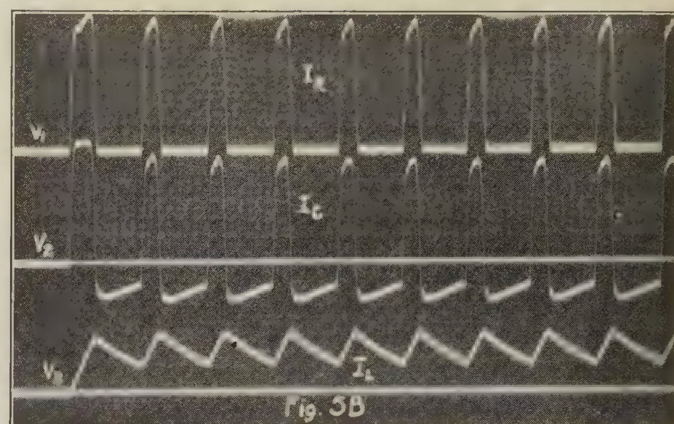

FIG. 5B—OSCILLOGRAMS FOR RECTIFIER CIRCUIT OF FIG. 3A

V_1 is rectifier current. V_2 is condenser current. V_3 is load current with 2.13 μ f. shunt capacity

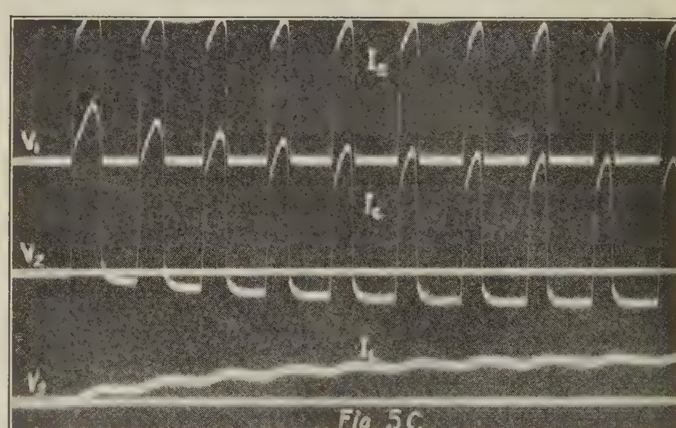

FIG. 5C—OSCILLOGRAMS FOR RECTIFIER CIRCUIT FIG. 3A WITH ONE TUBE

V_1 is rectifier current. V_2 is condenser current. V_3 is load current with 12.13 μ f. shunt capacity

e. m. f. V_3, is shown. The value of C_1 is 2.13 microfarads. The upper waves of V_1 show very well the dissimilar characteristics of the rectifier tubes. It is well to point out that in V_1 the wave forms above the axis represent the charging current, and below the axis, the discharge current into the load.

Removing either T_1 or T_2 from the circuit Fig. 3A

gives a half wave rectifier. The oscillograms in Figs. 5B and 5C show the effect of shunt capacity across the load resistance on the output current of the half wave rectifier. In Fig. 5B, C_1 is 2.13 microfarads; in Fig. 5C, C_1 is 12.13 microfarads. In both of these oscillograms, V_1, V_2, and V_3 are taken simultaneously, with V_1 the rectifier output current, V_2 the condenser current, and V_3 the resulting load current. In V_2 the wave forms above the axis give the charging current, and below the axis, the discharge current to the load.

Effect of Inductance on the Load Current Wave Form.

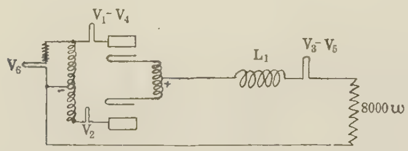

FIG. 6A—CIRCUIT DIAGRAM OF RECTIFIER WITH INDUCTANCE IN SERIES WITH LOAD RESISTANCE

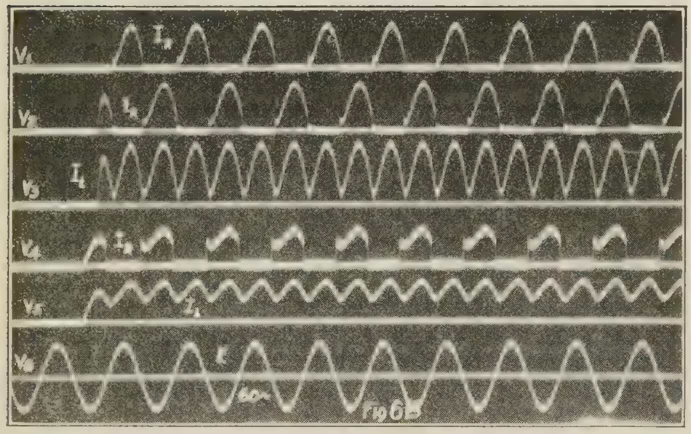

FIG. 6B—OSCILLOGRAMS FOR RECTIFIER CIRCUIT FIG. 6A

V_1 and V_2 are individual tube output current. V_3 is load current with L_1 7.5 henrys. V_4 is output current of one tube. V_5 is load current with L_1 = 30 henrys. V_6 is 60-cycle applied voltage

Introducing inductance into the load circuit, as illustrated in Fig. 6A, causes a reduction in the amplitude of the current ripple and also a large drop in the effective load voltage, because of the high IZ drop of the inductance. On the other hand, the shunt capacity as shown in Fig. 8A gives a higher effective load voltage than is obtained when both L and C are out of the circuit. This effect of the condenser is obvious from the discussion given above.

In the oscillogram of Fig. 6B, V_1, V_2 and V_3 were taken simultaneously with L_1, having an inductance of approximately 7.5 henrys, while V_1 and V_2 show the individual tube output and V_3 the load current. The small hooks on the wave forms of V_1 and V_2 show that the rectified current lags the impressed e. m. f. because of the series inductance.

The effect of increasing the series inductance to approximately 30 henrys is shown (Fig. 6A) by V_4, V_5, and V_6 in Fig. 6B, V_4 being the output of one tube (the output of the other tube being the same), V_5 the load current, and V_6 the impressed e. m. f. The ripple of V_5 is considerably smaller than that of V_3, and the hooks on the wave forms of V_4 are larger, indicating a greater angle of lag between current and impressed e. m. f. Furthermore, the load current ripple is now practically a sine wave of a frequency twice the input frequency of 60 cycles.

Increasing the inductance still further has only a very small effect on the load current ripple. Half wave rectification, with inductances in the load only, gives a slightly disturbed upper half of a sine wave. The oscillograms for the half wave rectifier are not shown here.

It has been demonstrated above that the amplitude of the load current ripple is reduced by increasing the

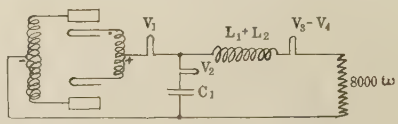

FIG. 8A—CIRCUIT DIAGRAM OF RECTIFIER WITH SERIES INDUCTANCE AND CAPACITY SHUNTED ACROSS RECTIFIER

$C_1 = 12.13\ \mu f.$ $L_1 + L_2 = 60$ henrys

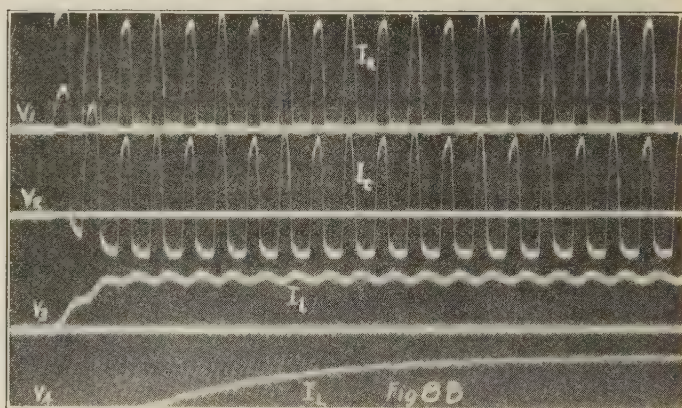

FIG. 8B—OSCILLOGRAMS FOR RECTIFIER CIRCUIT FIG. 8A

V_1 is rectifier current. V_2 is condenser current. V_3 is load current with 2.13 μf. shunt capacity. V_4 is load current with 12.13 μf. shunt capacity

time constant of the load circuit. For the circuit shown in Fig. 6A, with an inductance of $L_1 = 50$ henrys and a series resistance of 9000 ohms, the time constant is 0.00555 sec. The circuit in Fig. 3A with $C_1 = 12.13$ microfarads and a load resistance of 8000 ohms has a time constant of 0.097 sec. Therefore, the amplitude of the load current ripple should be much less for the circuit with shunt capacity than for the circuit with series inductance. This is clearly shown by the oscillograms, V_3 Fig. 3C, for the circuit with shunt capacity and, V_5 Fig. 6B, for the circuit with series inductance.

Effect of Inductance and Capacity on the Load Current Wave Form. The effect of capacity shunted across the

load resistance and the effect of inductance in series with the load resistance on the amplitude of the load current ripple have been shown above. By properly proportioning inductance and capacity, therefore, it should be possible to reduce the amplitude of the load current ripple to a negligible value.

In oscillogram Fig. 8B, for the circuit of Fig. 8A, V_1, V_2, and V_3 were taken simultaneously, V_1 showing the current from the rectifier, V_2 the condenser current with 2.13 microfarad capacity, and V_3 the load current.

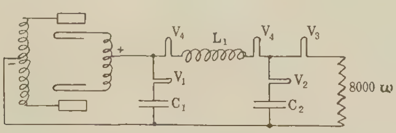

Fig. 9A—Circuit Diagram of Rectifier

Series inductance L_1 is 30 henrys. C_1 is 4.26 μ f. C_2 is 4.76 μ f.

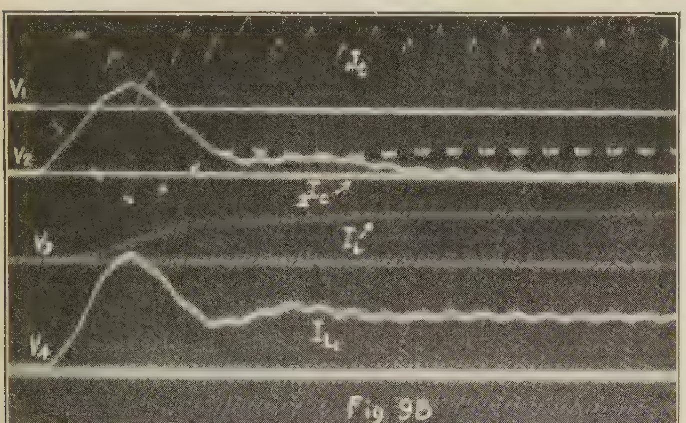

Fig. 9B—Oscillograms for Rectifier Circuit Fig. 9A

V_1 is condenser current C_1. V_2 is condenser current C_2. V_3 is load current. V_4 is current in series inductance

Increasing C_1 to 12.13 microfarads gives the load current shown by V_4, which is practically a straight line. The per cent ripple in this load current is 1.2 per cent and was determined by the method explained in Section 3 of this paper. With the oscillograph, the current shown by V_4 appears as a straight line. It is seen, therefore, that the oscillograph will not show a ripple which is less than about 2 per cent. Since a load current with a ripple of 2 per cent is not satisfactory for "B" battery supply for radio receiving sets, further filtering and other means for detecting the ripple are necessary.

Two more interesting oscillograms are shown to give the action of the second condenser in the filter shown in Fig. 9A. In the oscillogram of Fig. 9B for the circuit shown in Fig. 9A, V_1, V_2 and V_3 were taken simultaneously, with V_1 the condenser current of C_1, V_2 the condenser current of C_2, and V_3 the load current; V_4 is the inductance current and was taken separately, although timed nearly the same.

A starting transient is observed here, and is due to the charging of C_2, which had no charge at the start. The transient is observed to be slightly oscillatory but so damped that only two cycles are apparent. The effect is more pronounced in V_4. In the steady state, C_2 draws a small current, being charged by the 120-cycle current ripple and discharging into the load, thus reducing the load ripple still further. The load current, V_3 Fig. 9B, shows a smooth line.

The circuit, Fig. 10A gives an inverted L filter. Oscillograms, Fig. 10B, show V_1 the inductance current, V_2 the condenser current, and V_3 the load current, taken simultaneously, with C_2 equal to 2.13 microfarads. The wave forms V_4, V_5 and V_6 show these same currents but with C_2 increased to 12.13 microfarads.

Several interesting things are to be observed: First, the highly damped oscillatory transient due to the charging of C_2; second, on account of large shunt capacity and a proper series inductance, the ripples in the load current are less pronounced. Increasing the capacity, C_2, increases the transient and gives a smooth load current.

Section 3. Measurement of the Load Current Ripple by the Vacuum Tube Peak Voltmeter

The output current of a vacuum tube rectifier was found to be a pulsating current as illustrated in Fig. 2B.

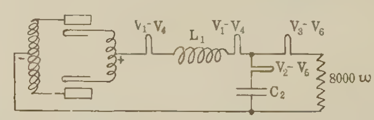

Fig. 10A—Circuit Diagram of Rectifier with Inverted L Filter

L_1 = 30 henrys, C_2 = 2.13 or 12.13 μ f.

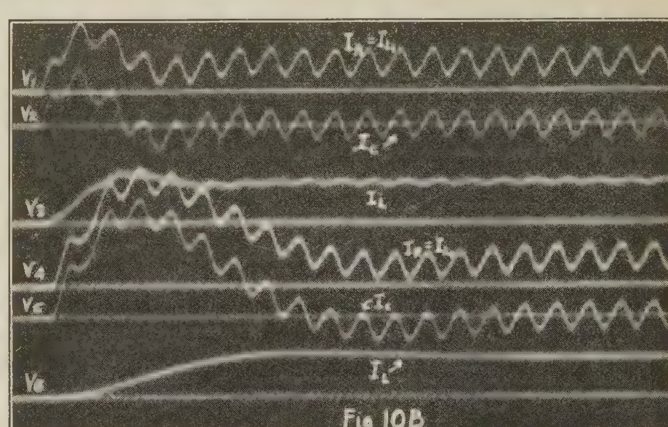

Fig. 10B—Oscillograms for Rectifier Circuit Fig. 10A

V_1 is inductance current. V_2 is condenser current and V_3 is load current when C_1 = 2.13 μ f. V_4 is inductance current, V_5 is condenser current and V_6 is load current when C_1 = 12.13 μ f.

It has been shown that the amplitude of the pulsations can be reduced by means of a filter with properly protioned series inductances and shunt capacities. It was also shown that the oscillograph would not detect a ripple in the load current less than 2 per cent. But a ripple of 2 per cent in the load current of a vacuum tube rectifier is too large for "B" battery supply for radio

receiving sets; therefore, the following method for measuring the current ripple was developed.

A current ripple may be looked upon as a periodic alternating current of some wave form superimposed upon a constant direct current. In this case of the output of a vacuum tube rectifier through a filter, the superimposed alternating current is practically a sine wave of 120-cycle frequency. By measuring the two

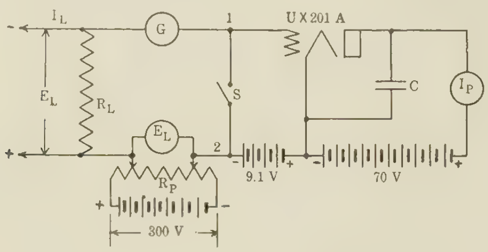

FIG. 11—CIRCUIT DIAGRAM OF VACUUM TUBE VOLTMETER

G = galvanometer. E_L = d-c. voltmeter. I_p = milliameter
R_L = rectifier load resistance

components of the load current, the ripple may be expressed in per cent by

$$\frac{I_{mac}}{I_{dc}} \times 100$$

Here I_{mac} is the maximum value of the a-c. component and I_{dc} is the d-c. component of the rectifier current. After analyzing several methods for measuring these two components of the load current, it was found that the vacuum tube voltmeter would probably be the most satisfactory. The results obtained show that this method is well suited for such measurements.

Fig. 11 shows the circuit diagram of the voltmeter as used for these tests. Here R_L is the load resistance of the rectifier, E_L the load voltage, and I_L the load current, which contains the ripple. A d-c. potentiometer circuit, capable of a voltage variation from 0 to 300 volts, is in series with the grid-filament circuit. The purpose of this potentiometer is: (1) to balance out the effect of the d-c. component and keep it from biasing the grid, (2) to measure the value of the d-c. component of the load voltage indicated by the meter E_L. When the switch S is closed, the galvanometer G is used to determine if the potentiometer voltage is equal to the d-c. component of the load voltage. The meter I_p indicates the plate current.

Since the plate current of a vacuum tube is a function of the applied grid voltage, this device can be calibrated and used as a peak voltmeter. The meter was calibrated by passing a known 60-cycle current through a known non-inductive resistance and applying the $I\,R$ drop to the terminals 1-2 of the meter with the switch S open. Normal grid bias, plate voltage and filament current were used. Since the voltmeter was calibrated on 60 cycles and used on 120 cycles, there is a possibility of a slight error in the readings, due to the fact that the plate current meter I_p will not read the 60-cycle and 120-cycle pulses the same. The error is so slight, however, that it can be neglected.

The calibration curve for this meter is shown in Fig. 12. Two calibration curves are shown, one from zero to 11 volts, and the other from 10.5 to 57 volts. In order that no grid current shall flow, the peak voltage to be measured should not exceed the value of the grid biasing battery voltage, in this case, 9.1 volts. With the grid at a positive potential of 15 volts, the grid current is negligible in comparison with the load current, 0.05 amperes, and therefore voltages up to 25 volts can be measured with a high degree of accuracy and higher voltages can be measured with nearly the same degree of accuracy. The plate current shown by the calibration curves in Fig. 12 is not biased to zero. This is done so that a known zero can be maintained and any deviation noted and corrected. The low-range calibration curve is a close approximation to the plate current-grid voltage static characteristic curve of the UX-201A vacuum tube.

To use the vacuum tube voltmeter, the grid, filament, and plate battery voltages are adjusted to their proper calibrated values. With the complex current in the load resistance, the approximate value of E_L is determined and the potentiometer set to that value. The switch S is closed and R_p varied until the meter G reads zero. Then S is opened and the reading of I_p noted. The corresponding value of the a-c. component of the load voltage is obtained from the calibration

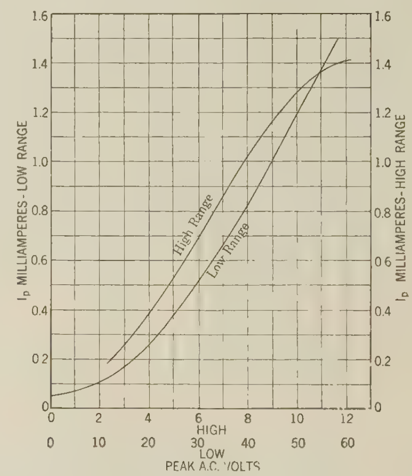

FIG. 12—CALIBRATION CURVE FOR VACUUM TUBE VOLTMETER

curve, Fig. 12. The reading of E_L gives the d-c. component. From these two values, the per cent ripple can be calculated as explained above. In order to obtain satisfactory results, the voltage applied to the rectifier must be constant because very slight changes in the primary voltage will produce large variations in the voltmeter readings across the load. For these tests a constant a-c. voltage was obtained from a synchronous motor-generator set with battery excitation on the generator.

The various filter circuits shown in Fig. 13 were studied with the vacuum tube voltmeter, for which purpose, the full wave rectifier was used with a load resistance of 5100 ohms. With this resistance across the rectifier and no filter, an r. m. s. load current of 0.050 amperes was obtained. The load voltage E_L obtained with the different filter circuits with constant input voltage is shown in the figure. The effect of varying the shunt capacity for each of the filter circuits

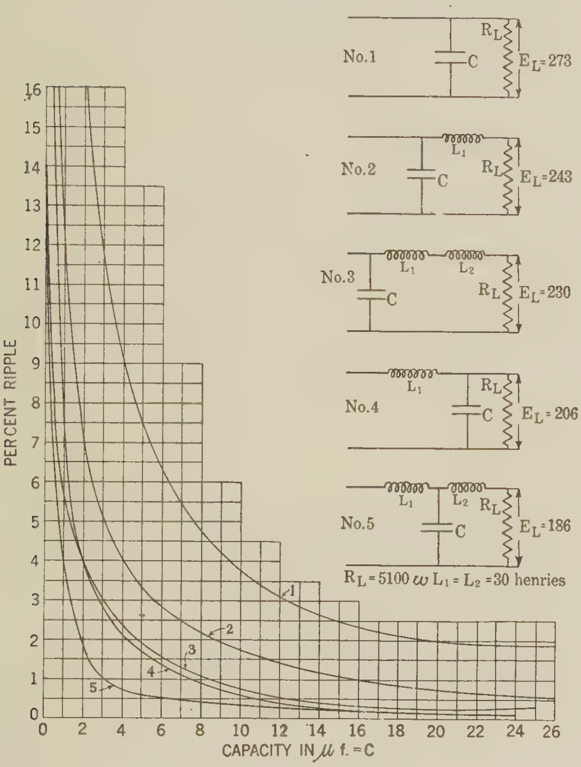

FIG. 13—EFFECT OF VARYING CAPACITY IN VARIOUS TYPES OF FILTER CIRCUITS

is also shown in Fig. 13. The results of these tests show that the filters with a small per cent ripple in the load voltage have a high-voltage drop. By combining several of the types of filters shown, one with a small per cent ripple and a low-voltage drop can be obtained.

One section of a Pi-type filter with the test results is shown in Fig. 14, and a single section of a T-type filter with test results is shown in Fig. 15. The Pi-type filler gives a current with a smaller ripple and also has a lower voltage drop than the T-type filter. The T filter can be improved by adding a capacity C_2 across the load as shown in Fig. 16. The results of the test show that the per cent ripple has been reduced to a negligible value, but that the voltage drop in the filter remains unchanged. By adding a third capacity C_1, as shown in Fig. 17, the desired results are obtained; that is, the ripple is reduced to a value that cannot be detected by the voltmeter and the voltage drop is the same as for the Pi-filter shown in Fig. 14.

By inserting a pair of high-resistance receivers in the plate circuit of the vacuum tube voltmeter, the ripple can be detected audibly. A ripple that was just audible was found to be equal to 0.08 per cent. To check these results, a small portion of the load voltage was impressed upon the terminals of a 1 to 6 audio-frequency transformer and the secondary connected to the terminals 1-2 of the vacuum tube voltmeter. With a plate current of one milliampere, the hum was just audible. This method of test was used for the circuit shown in Fig. 17. When using the audible method of detecting the ripple, it was found that the removal of the shunt capacity across the load (C_3, Fig. 17) introduced a bad circuit noise caused by high frequencies in the load current. It was also noted that a capacity of at least two microfarads should be used, at C_3 Fig. 17, to by-pass the high frequencies that tend to enter the load.

The circuit devised for measuring the two components

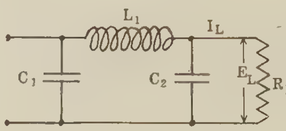

FIG. 14—E_L = 250 VOLTS, I_L = 0.049 MILLIAMPERE

C_1 μ f.	C_2 μ f.	Per cent ripple
2.13	5	0.30
4.26	5	0.20
4.26	10	0.08

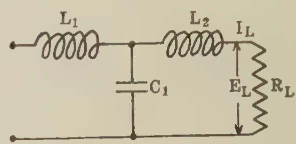

FIG. 15—E_L = 186 VOLTS I_L = 0.037 MILLIAMPERE

C_1	Per cent ripple
2.13	1.62
4.26	0.70
9.26	0.40
14.26	0.27

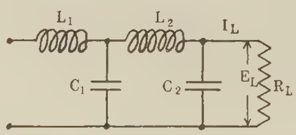

FIG. 16—E_L = 186 VOLTS I_L = 0.037 MILLIAMPERE

C_1	C_2	Per cent ripple
5.0	2.38	0 +
5.0	4.76	0 +
10.0	4.76	0 +

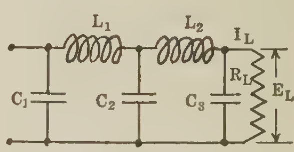

FIG. 17—E_L = 250 VOLTS I_L = 0.049 MILLIAMPERE

C_1	C_2	C_3	Remarks
2.13	5	2	Slight hum
4.26	5	2	Very slight hum
4.26	5	4	Not audible
4.26	10	4	Not audible

FIGS. 14, 15, 16 AND 17—FILTER CIRCUITS WHICH WERE TESTED

The amount of ripple and the load voltage for different condenser values are shown herewith. In all cases L_1 and L_2 equal 30 henrys each and R_L equals 5100 ohms

of the load current by means of the vacuum tube voltmeter is believed to be a new application for this type of instrument.

SECTION 4. CALCULATIONS OF PER CENT VOLTAGE FLUCTUATION

The percentage voltage fluctuation in the load resistance may be calculated by the formulas given by H. J. Van Der Bijl in his book above mentioned. For

the type of filter shown in Fig. 8A, the formula is as follows:

$$\frac{\delta E_L}{E_L} = \frac{2\pi}{\omega C_1 \sqrt{R_L^2 + L^2 \omega^2}}$$

$C_1 = 12.13 \times 10^{-6}$ farads, $L = L_1 + L_2 = 60$ henrys, $R_L = 8000$ ohms and $\omega = 2\pi \times 120 = 754$. The calculations give a percentage voltage fluctuation of 1.49 per cent. The value obtained from the measurments by means of the vacuum tube voltmeter is 1.2 per cent.

For the type of filter shown in Fig. 9A, the following formula applies:

$$\frac{\delta E_L}{E_L} \quad \frac{2\pi}{\omega C_1 [R_L^2 (1 - L_1 C_2 \omega^2)^2 + L_1^2 \omega^2]^{1/2}}$$

$C_1 = 4.26 \times 10^{-6}$ farads, $L_1 = 30$ henrys, $C_2 = 5.0$ 10^{-6} farads, $R_L = 8000$ ohms, and $\omega = 2\pi \times 120 = 754$. The calculations show a percentage voltage fluctuation of 0.289 per cent. The vacuum tube voltmeter method of measuring the percentage fluctuation gave 0.20 per cent.

Section 5. Conclusions

In order that the voltage drop in the filter circuit should not be too high, the series inductance should not be larger than required to produce a current without ripples. For the filter circuits discussed above, each inductance for the working load current should not be less than 25 henrys. The resistance of each inductance should preferably be kept low,—not greater than 250 ohms. To further reduce the voltage drop, a shunt capacity of not less than four microfarads should precede the inductances to provide a low impedance shunt for the ripple current.

To obtain a rectified current with negligible ripple, two Pi-type filter sections will generally be the maximum number required if shunt capacities equal to, or larger than, four microfarads are used. A single Pi-type filter section can be used to give a ripple of approximately 0.10 per cent if both condensers have a capacity of six microfarads, or larger, and if the series inductance is large, 25 henrys or larger.

Alternator Characteristics Under Conditions Approaching Instability

BY JOHN F. H. DOUGLAS[1] and EDWARD W. KANE[1]
Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*In this paper the comparatively recent discovery of generator instability is discussed. A method of testing synchronous machinery in the unstable as well as in the stable range is described. The results of tests performed on two machines is shown and discussed. The conclusion is drawn that the design of customary machines will have to be improved, synchronous condensers installed on many long lines, or inefficient underloading of units will have to be tolerated.*

Introduction

UNTIL recent years the loads on power systems were with a predominately lagging current. While the regulation of the generators was sometimes quite poor, nevertheless the operation showed high stability and the field rheostats were adequate to control the voltage without loss of synchronism. Perhaps because of this fact, and perhaps for other reasons, textbooks have shown practically no diagrams or full-load saturation curves for leading power factors. The student might well obtain the impression that the solution of the problem of regulation for such power factors would be carried out without difficulty, but when one attempts to carry out the solution, one meets with several obstructions of a theoretical nature.

Of late years the voltage and length of transmission lines have been increasing and the number of interconnections growing. Consequently the leading current load is becoming quite an item. At the same time due to attempts to improve customer power factor the lagging current load has shown a tendency to decrease. As a consequence, some curious phenomena have been noticed and reported: 1. A very unstable voltage on light loads when the line charging current is carried by too few units. 2. Inadequate field rheostat resistance to keep the voltage down. 3. The combination of lines and generator becoming self-exciting, that is, a resonance between the inductance of the machine and the capacity of the line, giving high voltage with the field circuit open. 4. Generators remaining in step with small reverse field excitations. 5. Generators slipping a pole when the reversed field excitation is increased, and before the voltage is brought down to normal. When this pole slipping takes place, there is a surge which causes the voltage to rise to considerably above normal.

The difficulties met in attempting to apply the

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Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Chicago Ill., Nov. 28-30, 1927.

A. I. E. E. rule for leading current loads is well illustrated in Fig. 1. The curve *O X* is the no-load saturation curve; *F Y* is the full-load zero power factor lagging saturation curve, and *F Z*, the full-load unity power factor saturation curve. The zero leading power factor full-load saturation curve is shown by the line *A B C D*, or the line *A B C E*. The segment *A B* is as much above the no-load saturation curve as the line *F Y* is below it, as required by the A. I. E. E. rule. For saturations below this point, one is in doubt as to just how to proceed, but if it be assumed that the

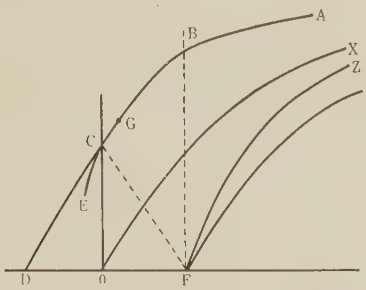

Fig. 1—Illustrating Difficulties in Estimating Zero Power Factor Leading Saturation Curves

synchronous impedance is a constant, the segment *B C* would be drawn parallel to the line *O X*. For voltages below *O C* we meet another difficulty. If we continue the line toward the point *D*, we have a characteristic which, unlike the lagging characteristics, does not pass through the point *F*. If we reverse the segment *C D*, we are unable to account for the operation with reversed field currents and we must imagine a sudden 180-deg. shift of phase at the point *C*.

With the peculiar behavior of synchronous machinery reported and the obvious defects in the more usual theory before us, we determined to make some tests with leading current conditions and if possible, try to extend them into the region of unstable operation.

Preliminary Tests

Our first tests were of a qualitative character. We sought to verify for ourselves just what took place when a generator lost control of its load. We connected an a-c. generator to a synchronous motor load, but did not take power from the motor. We overexcited the motor, loading the generator with leading current of low power factor. We included a field ammeter, armature ammeter and voltmeter in the generator circuits. We attached a G. E. slip meter to the synchronous motor shaft, which we excited from the same 60-cycle supply that furnished power to the synchronous motor which drove the generator being tested. The amount of leading current was held roughly constant and varied the generator field current and generator voltage. The characteristic *A B C E* in Fig. 1 was obtained. At the point *E* there was a surge of voltage and current, the generator forged ahead one pole or the motor slipped a pole as indicated by the slip-meter differential turning 90 electrical deg. The voltage after the surge corresponded to the point *G*.

This experiment was considered to prove, in a general way, the results previously reported, and to indicate that further tests were worth while.

Tests of Generator Characteristics by a Pump Back Method

First of all it was determined to employ an opposition method of testing, in order to obtain, if possible, characteristics of the unstable condition of operation. This procedure was successfully used by one of the authors in testing synchronous motors in their unstable range, and reported on in the A. I. E. E. Journal, Jan. 1925; p. 11. It was found that the connections in Fig. 2 were suitable. The generator (1) was directly connected to an identical machine (2) with a movable stator controlled by the hand wheel (3). These machines were 15-kv-a. 1200 rev. per min. machines rated at 220 volts with a Y-connection. Machine (2) absorbed the power generated by (1). The losses were sometimes supplied by a d-c. motor belted to the set, and sometimes, from the connection shown to the 60-cycle line. The amount and phase of the current output of the generator could be controlled by the hand wheel (3) and rheostats (4) and (5).

The output of the generator was measured by a polyphase wattmeter; sometimes by the three-wattmeter method, using the neutral point on one machine. The line current and voltage were measured with the aid of a polyphase board. The phase angle of the terminal voltage with respect to the pole axis was

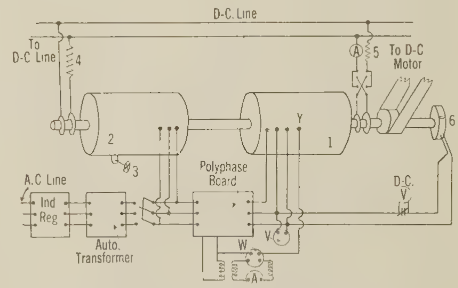

Fig. 2—Connections for Determining Complete Excitation Characteristics of Alternator

measured with the contactor (6). This contactor was the usual point-by-point wave form apparatus, and was connected in series with one phase of the generator and a d-c. voltmeter, which was shunted by a condenser. The movable arm carrying the contacts could be turned about and their position noted on a degree scale. They were turned at all times so that the voltmeter gave a zero reading. The shift of the contacts from no load to the point under observation indicated the amount that the pole axis shifted with respect to the terminal voltage. This use of the contactor was developed by

Messrs. Edwin Baldwin and Earle Lashway when seniors at Marquette University.

In the first series of tests, the wattmeter was at all times kept at zero by the hand wheel. Currents were circulated by maintaining a difference in the excitation

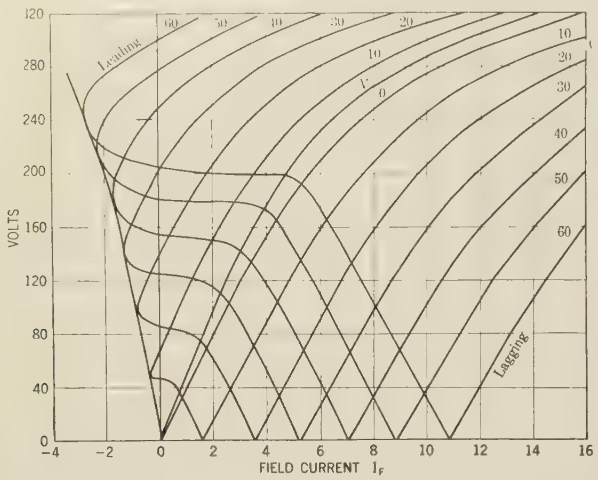

Fig. 3—Excitation Characteristics of Alternator Zero Power Factor Leading and Lagging for Constant Armature Current

between the two machines. Runs were taken for armature currents of 60, 50, 40, 30, 20, and 10 amperes. Voltage, field current and phase shift were recorded for each run. Owing to the fact that when the generator field was large, the motor field was small, and *vice versa*, the voltage seldom exceeded 270 volts. For the higher

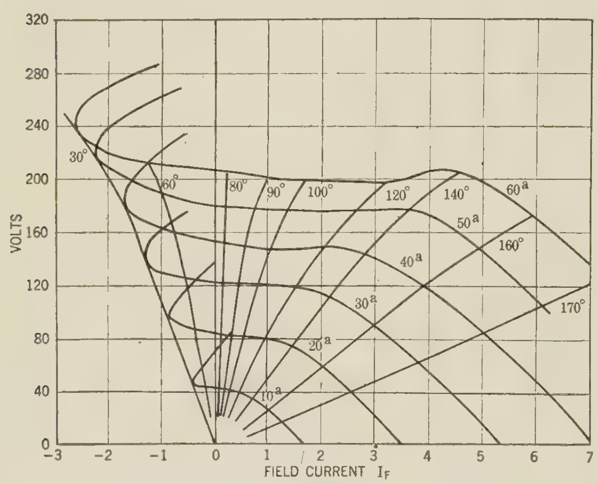

Fig. 4—Zero Power-Factor Characteristics Leading Current in Region of Unstable Operation, for Various Armature Currents and Various Angles of Pole Slip

voltages, therefore, the set was synchronized with the a-c. line. The data were in such form that it could be directly plotted in Figs. 3 and 4. Fig. 3 shows the voltage characteristics for zero power factor, Fig. 4 shows also the phase displacements in the unstable range.

It is to be observed that stable operating condition is shown with reversed current in the field, also that the lagging and the leading characteristics join at a common point F, and that the shift of 180 deg. is only gradually accomplished in the unstable range. A phase shift from 30 deg. to about 160 deg. occurs at a practically constant voltage. These "nose" shaped generator characteristics are believed to be novel.

Since a transmission line connected to a generator at no-load represents a zero leading power factor load of constant ratio of amperes to volts, it was thought to be of interest to take a series of cross curves from Fig. 3 representing constant equivalent single-phase "Susceptances" of values from 0.00 to 0.2 in steps of 0.02 amperes per volt. These cross curves are plotted in Fig. 5. It will be seen that with a charging susceptance of large value, the characteristics are quite steep and in some cases practically vertical. Under these con-

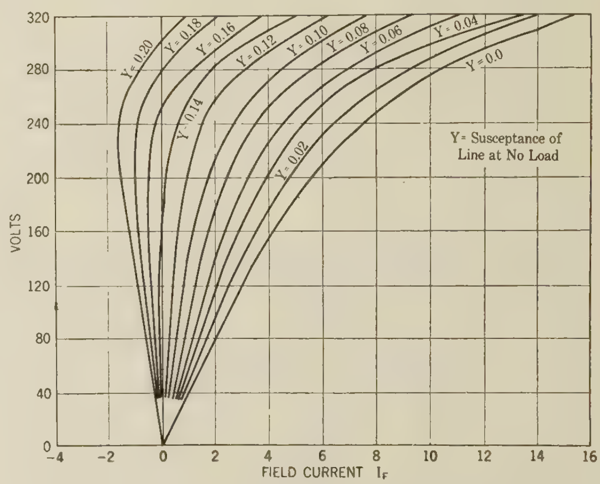

Fig. 5—Excitation Characteristics of Alternator at No-Load and Various Line Capacities

ditions, voltage control is difficult. If it is not feasible to use synchronous condensers on such a line and under-excite them at light load, then it will be impossible to shut down too many units at light load. Of course if a considerable improvement in generator design is made, this conclusion may be modified.

The second series of tests was made at a current of 40 amperes; practically full-load rated current. For convenience, at voltages of less than 270 volts, each run was made with a constant phase displacement between the two machines. Above 270 volts, each run was made for a constant terminal voltage. In each run, the power factor was varied from zero lagging to zero leading by a proper variation of the two field rheostats. For each run the terminal voltage, power-factor, and phase displacement of the rotor was plotted against the field current. Cross curves were taken from these for constant power factors and constant phase displacements of rotor. Curves for 0, 70, and 90 per cent lagging, and for 100, 90, 70, 50, 20, and 0 per cent leading power factors were taken. Curves for 10, 20, 30, 40, 50, 60, and 90 deg. phase displace-

ment were taken. All these curves are plotted in Fig. 6.

It is to be observed that all the full-load saturation curves pass through one common point F; also that for power factors of less than 20 per cent leading current, it is possible to obtain stable operation with reversed field current. The line $E\ S\ F$ passes through all the points where the curves are vertical and may be taken as the limit of stable operation. Below and to the left of this line, generator operation is unstable; that is, it will forge ahead a pole if it is free to do so. The phase displacements of the pole axis from the terminal voltage are small in the stable operating range and are considerably less at high saturations.

The hope for improved design and increased stability consists of being able to extend the nose of these curves toward the region of reversed field currents, and to lower the lower edge of this nose at the place where it intersects the Y-axis. Attention will be called in a later paragraph to the constant of the machine, which requires improvement.

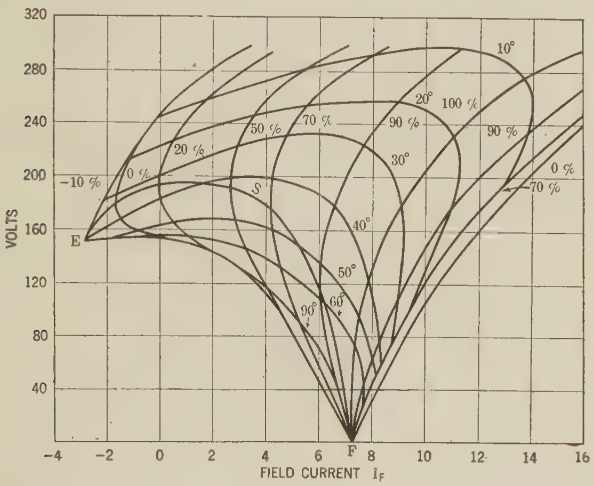

Fig. 6—Full-Load Saturation Curves by Test Loci of Constant Power Factor and Pole Slip Angle. Locus ESF of Stability Limit

Tests of Generator Stability with Direct Loading

In the endeavor to determine the locus of stable operation, such as $E\ S\ F$ in Fig. 6, by direct loading and actual observation of pole slipping, we took a 5-kv-a., 1800-rev. per min. 220-volts, three-phase Northwestern machine and connected it according to the diagram in Fig. 7. In this figure (1) is the alternator to be tested, driven through a belt by the d-c. shunt motor (2). The alternator delivered its power to synchronous motor (3), and this, in turn, to the alternator (4) and the a-c. line. By controlling the rheostat (5) in the field of the d-c. shunt motor the amount of power circulated could be controlled. The amount of leading current taken from the alternator could be controlled by the field rheostat (6) of the synchronous motor. The field of the alternator (1) was controlled by reversing switch (7) and rheostat (8). For convenience each run was taken at a constant field current of the alternator tested.

For each point of data, the field rheostat of the d-c. motor was weakened until the generator slipped poles. This pole slipping was easily identified by the current and voltage surge which took place. Some practise was required, however, to secure readings at the point just before the pole slipping took place. It was observed that with reversed field current on the generator, only a small load could be carried without pole slipping taking place. Under these conditions, the generator slipped only one pole and regained synchronism. When the fields were excited in the normal manner, a considerably greater load could be carried without pole slipping; but when the critical load was exceeded, the generator fell out of step completely and continued to slip poles.

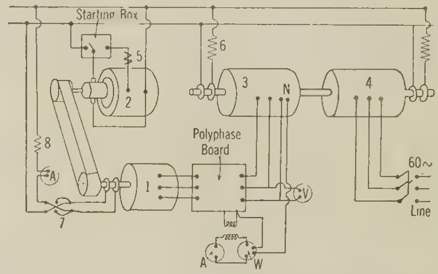

Fig. 7—Connections for Determining Point of Pole Slipping in an Alternator

Readings of generator voltage and watts were taken for the slipping point and plotted against the armature currents, for six runs, during which the alternator field currents were respectively 2, 1.5, 1.0, 0.5, 0, and −0.5 amperes. Cross curves were taken from these for armature currents of 2, 1.5, 1, 0.75, and 0.50 times rated current. The cross curves thus obtained are shown in Fig. 8.

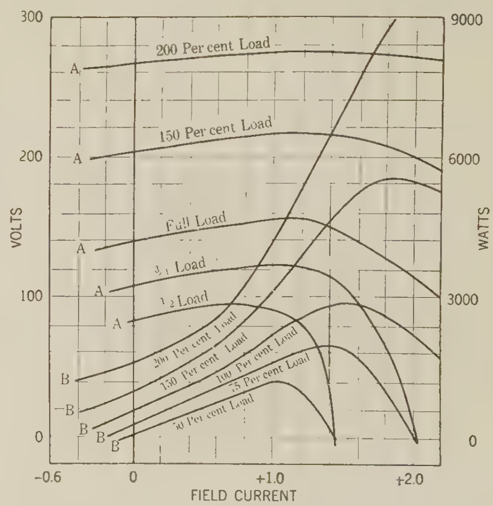

Fig. 8—Stability Limits of Voltage and Power in an Alternator for Various Current Loads

The curves shown agree in form fairly well with the

curve $E\ S\ F$ in Fig. 6. The voltage of the generator is too high at conditions of large leading current. The chief conclusions to be drawn from these curves are as follows: (1) The criterion of stability assumed,—namely, a vertical volt field-current characteristic,—is borne out. (2) Generator operation is unstable below a voltage which varies in proportion to the current load on the machine. (3) To operate at normal voltage in a stable manner, the leading current load must be kept down to a certain fraction of the rating connected to the line. It is to be hoped that improved generator design will increase that fraction.

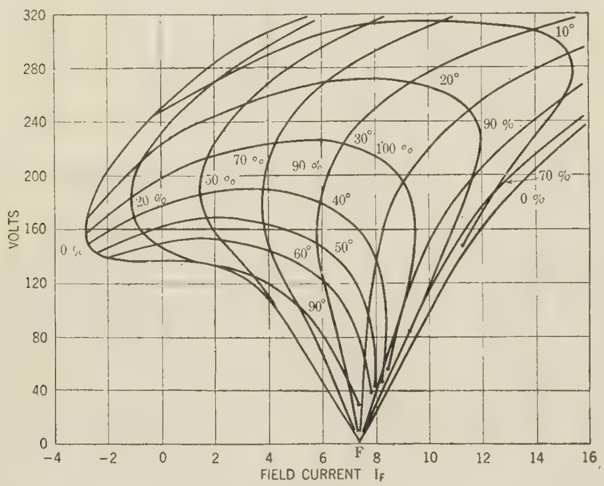

Fig. 9—Full Load Saturation Curves Computed by Blondel. Two Reaction Diagram, Loci of Constant Power Factor and Pole Slip Angle.

Predetermination of Generator Characteristics with Leading Current

In the A. I. E. E. Journal for February 1927, (p. 109), one of the authors proposed a method for computing the performance of synchronous machines. It was thought that it would be interesting to compute a series of curves such as shown in Fig. 6 by the method there outlined. It was felt that in view of the unusual and novel shape of the curves in Fig. 6, an agreement would give a satisfactory confirmation of the theory. The constants of the machine tested in this paper for two-phase connection are reported in the article cited. For the three-phase connection the following were assumed:

Direct armature reaction 7 amperes field current equivalent to 40 amperes in the armature. Transverse armature reaction, 3.5 amperes in the field equivalent to 40 amperes in the armature. Direct reactance 1/3 ohm per phase of Y, transverse reactance zero, and resistance 1/6 ohm per phase of Y. Saturation curve is as shown in Fig. 3.

With the constants in the above paragraph, the characteristics shown in Fig. 9 were computed. These should be compared with Fig. 6. We consider the agreement is very good, and believe that further theoretical studies of synchronous machines should be based on some form of the Blondel two-reaction theory.

The extent of the "nose" of the curves and the lower intercept of the nose on the Y-axis seems to depend chiefly upon the constant of transverse reaction.

Conclusions

In this report various remarks have been made to point out results of significance. The most general conclusion to be drawn is this: By a reduction of the value of the transverse reaction with improved design, there is a hope for machines of greater stability and consequent improved behavior under conditions of low leading power factor.

The problem of stability is likely to become more acute as the voltages, lengths of transmission line, and the number of system interconnections increase, so that it is hoped that the manufacturers will be able to improve the stability of their machines.

HYDROELECTRIC DEVELOPMENT IN PALESTINE

The necessity of importing all its fuel has been the most serious handicap to the industrial development of Palestine, and the principal factor in the future economic progress of the country is the Rutenberg project for hydroelectric development.

The Rutenberg plan, which has the official sanction of the Palestine Government in the form of a concession for 70 years to the Palestine Electric Corporation (Ltd.), Tel-Aviv, Palestine, calls for the harnessing of the Jordan River at intervals from its source to the point where it empties into the Dead Sea, in addition to the utilization of the waters of the Yarmuk River in the same manner. The first dam will be constructed at the point where the Jordan River leaves Lake Tiberias (the Sea of Galilee) with a power house at the town of Abadieh. Between these two points there is a fall of 40 meters in 8 miles.

The promoters assert that by using the Lake of Tiberias as a natural reservoir the neighboring country will be insured of a steady supply of water throughout the year, whereas at present this section usually suffers from drought every year during the dry season.

High-tension lines of 66,000 volts will run from the first power house to transforming stations located at the main centers of consumption, where the power will be redistributed over lines carrying 15,000 volts for the country districts and 6000 volts for the towns.

It has been estimated by the promoters that when the first stage of the development is completed a supply of 70,000,000 kilowatt-hours of energy per year will be provided and that consumption, according to the present requirements, will be 20,000,000 kilowatt-hours a year, which will leave a considerably surplus for new industrial enterprises.—*Commerce Reports.*

Influence of Internal Vacua and Ionization
on the Life of Paper Insulated High-Tension Cables

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and
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Synopsis.—*At the end of the year 1926 the High-Voltage Laboratory of the Electrotechnical Institute in Leningrad undertook an experimental research in order to study the influence of internal vacua and ionization on the life duration of paper insulated high-voltage cables, as well as to clear up the conditions under which such vacua may occur.*

W. A. Del Mar[3] *drew attention to the importance of internal vacua in high-voltage cables and pointed out the three probable causes of their appearance, namely:*

1. Temperature changes after installation of the cable, which produce a change of volume of air and oil in the cable in view of the different thermal expansion coefficient of lead and insulation of the cable.

2. Residual deformations, occurring when the cable is put on a reel and taken off it afterwards.

3. Changes in chemical structure in the impregnating compound under the influence of ionized air, which produce a decrease of volume of the compound.

The aim of the research was to clear up the part of the above mentioned causes in the formation of internal vacua, then to determine the values of those vacua and the decrease of life duration of the cable under the influence of the latter.

The research is not yet finished and only its preliminary results are reported on these pages.

* * * * *

Object of Investigation

As an object of investigation a high-voltage cable was taken, the design of which is reproduced in Fig. 1.

The cable consists of three cores, each having a thickness of insulation of 10 mm. (25/64 in.) and each covered with a lead sheath. The three cores are wound together into a three-phase cable and are protected by a

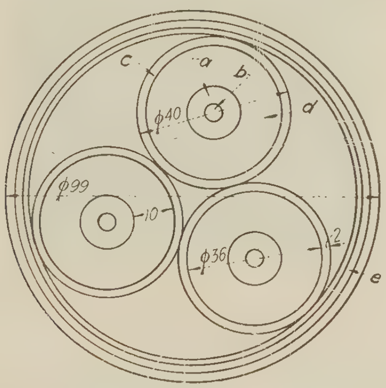

Fig. 1—Cross-Section of 35-Kv. Cable Used in Tests

a. Outer copper conductor
b. Inner conductor for Lypro cable protection
c. Lead sheath
d. Paper insulation
e. Double steel ribbon armor

double steel ribbon armor. The working pressure of the cable is 35 kv. with grounded neutral and the working pressure for each phase is 20.2 kv. The conductor of each phase is split into two concentric stranded conductors. The inner conductor serves for cable protection by the Lypro system.

The tests were made with single conductors of the cable having a length of 10 m. and with grounded lead sheath.

Conditions of Tests

During the performance of tests chief attention was drawn: (1) to the control of internal vacua, (2) to the electric field design on the end of cables under tests, and (3) to the elimination of the cable end influence during loss measurements.

The ways of propagation of air in the cable were studied in order to work out the best method of control of the internal vacuum in the cable. For this purpose different methods of pumping the air out of the cable and of the manometer connections were tried. These tests showed that the propagation of air in the cable takes place chiefly along the stranded core in the inner part of it and immediately on its surface.

The insulation of the cable presents in most cases a medium quite impenetrable for air. Air can be concentrated in single bubbles between the insulation and the lead sheath, but it cannot propagate along the cable. In view of these facts the pumping out of the cable of air was made from one of its ends and the internal vacuum was controlled by two manometers connected with both ends of the cable.

In most cases the same pressure on both manometers connected with both ends of the cable was established during a few seconds. But in certain special cases obstacles were found in cables which prevented the longitudinal propagation of air.

As previously mentioned, the insulation of cables presents a medium quite impermeable for air. But in certain cases air may be propagated from the conducting core to the lead sheath by bifurcated paths between the sheets of paper strands of the insulation. This explains the leakage of air through the insulation of the cables'

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1. Professor at the Electrotechnical Institute of Leningrad.
2. Electrical Engineer and Teacher at the High-Voltage Laboratory of the Electrotechnical Institute in Lenigrad.
3. William A. Del Mar, *The Effect of Internal Vacua Upon the Operation of High-Voltage Cables.* A. I. E. E. Trans. 45, 1926, p. 572.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 13-17, 1928.

ends, for the performance of tests necessitated the taking off of the lead sheath on the ends of the cable on a length of 1 m. In some cases the leakage was so considerable as to make difficult the maintenance of a constant vacuum in the cable. The control of the electric field on the ends of the cable was accomplished

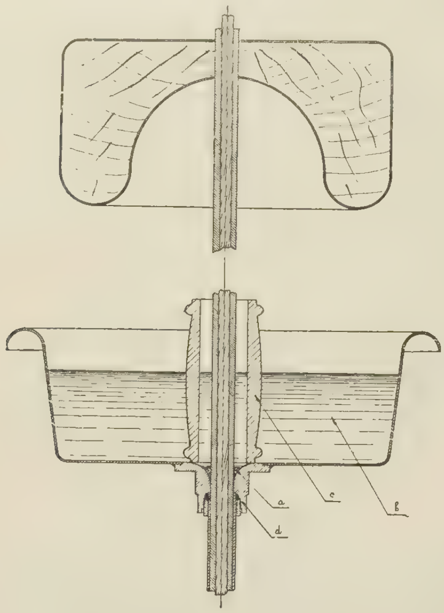


Fig. 2—Cross-Section of Cable Terminal

a. Hemp packing
b. Transformer oil
c. Porcelain bushing
d. Stuffing box

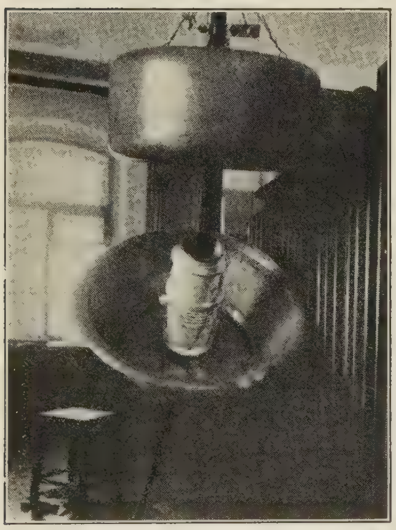


Fig. 3—Cable Terminal

by means of end insulation, schematically shown in Fig. 2 and on the photograph Fig. 3.

The upper electrode was made of wood and its surface was covered with tin-plate. The lower electrode is metallic.

On Fig. 2, *a* is a hemp packing, *b*, transformer oil, *c*, a procelain bushing, and *d*, a stuffing-box. The test of such a cable end insulator showed that its spark-over voltage is about 130 kv. This design of the cable end insulator provides quite a satisfactory form of the electric field on the ends of the cable, so that the breakdown of the cable during the tests occurred always somewhere in the middle of the cable, but not on its ends. If the curvature of the stuffing-box were made not along the arc of a circle, but along another more suitable curve, the spark-over voltage of such a cable end insulator could be noticeably increased without increase of its dimensions.

The elimination of the influence of cable ends on the measurement of losses in the cable was performed in the following way. At a certain distance from the ends of the cable two circular grooves 2 mm. wide were cut whereby the lead sheath was divided into three parts. The middle part was connected to Shering's

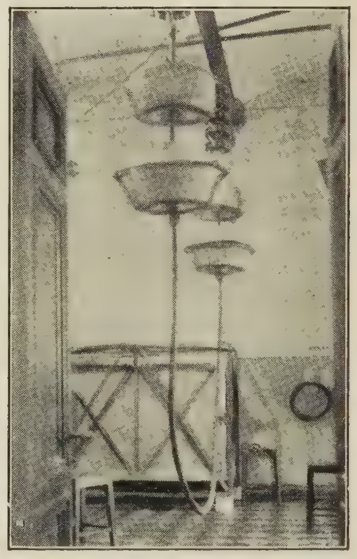


Fig. 4—Cable Ready for Test

bridge for measuring the loss and the two outer parts were grounded and formed guard rings.

After the sample of the cable was prepared for the tests, the cable was hung on two strings of insulators, as shown in Fig. 4.

The test voltage was derived from three Koch & Sterzel transformers, 0.5/125 kv., which could be connected in series. The voltage control was effected by means of a potential regulator made by the same firm. The study of the voltage curve of the potential regulator showed that when the latter was fed from 500 volts, a sinusoidal curve was obtained with one transformer only for voltages above 47 kv. If the potential regulator was fed at 110 volts, its voltage curve proved to be sinusoidal also. Therefore, for voltages under 50 kv., the potential regulator was fed at 110 volts and three high-voltage transformers were put in series. For voltages above 50 kv. the potential regulator was fed at 500 volts and only one high-voltage transformer was used.

In all these cases, the voltage curve was of a good sinusoidal form, as indicated by oscillograms.

Dielectric loss measurement was made by means of a Schering bridge. The air standard condenser was of a flat type with three plates, the middle of which was connected to the high-voltage winding of the transformer. The working surface of the plates (without

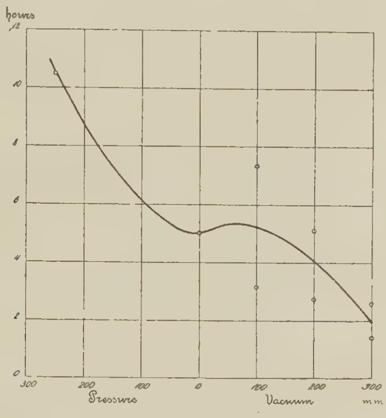


FIG. 5—VARIATION OF CABLE LIFE WITH PRESSURE AND VACUUM AT 60 KV.

guard rings) was equal to 17,840 cm.[2] The distance between the plates could be changed in such a way that even for very low voltages, about 3 kv. the power

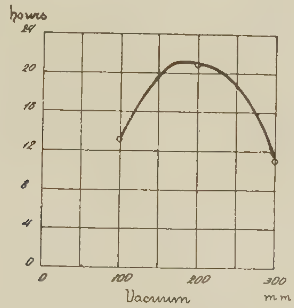


FIG. 6—VARIATION OF CABLE LIFE WITH VACUUM AT 50 KV.

factor could be accurately measured to three significant figures.

To clear up probable errors in the measurement of losses, phase displacements in the resistors were measured by means of a compensation method. This was also done with the parasitical capacities (capacity of the connecting conductor of the bridge and the capacity of the non-inductive resistances). These measurements showed that the largest probable error does not exceed a few seconds of phase displacement.

During the loss measurements the bridge was controlled in the following manner. After a measurement of the loss angle in the cable, a known non-inductive resistance R_0 was put in series with the latter and the loss angle was again determined. For a voltage E and a capacity C of the cable the loss in the non-inductive resistance can be calculated as follows:

$$J^2 R_0 = E^2 \omega^2 C^2 R_0$$

This loss must equal the difference of losses measured in the two cases mentioned above. Agreement between the results of measurement and calculation indicates normal operation of the bridge. Such a proof of the bridge was made several times and always presented quite satisfactory results.

LIFE DURATION OF CABLE IN FUNCTION OF INTERNAL VACUA

For the determination of the life duration of the cable in function of internal vacua, different vacua

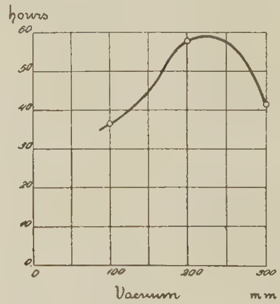


FIG. 7—VARIATION OF CABLE LIFE WITH VACUUM AT 42.6 KV.

were created in the interior of the cable and the latter was put under different voltages. During each test the vacuum and the voltage were held constant and the lapse of time was noticed, until breakdown of the cable occurred. As it was impossible to close the ends of the cable hermetically, as already pointed out, it proved

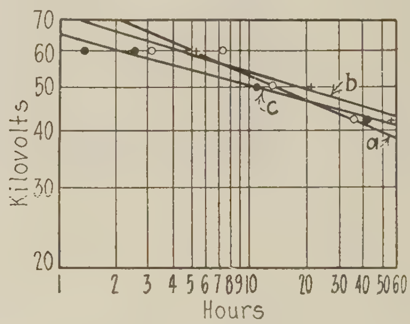


FIG. 8—VARIATION OF CABLE LIFE WITH VOLTAGES AT DIFFERENT VACUA

a. 100 mm. vacuum
b. 200 mm. vacuum
c. 300 mm. vacuum

necessary to renew the vacuum periodically. This was done without taking off the voltage. The permitted variations of the vacuum were ± 5 mm. barometric pressure. But in several cases, when the leakage of air through the cable insulation was small, after the voltage was put on the cable, an increase and not a decrease of the vacuum was observed. This can probably be explained by chemical changes occurring in the impregnating compound under the influence of

ionized air and accompanied by a volume decrease of the compound, as suggested by item 3 of the synopsis.

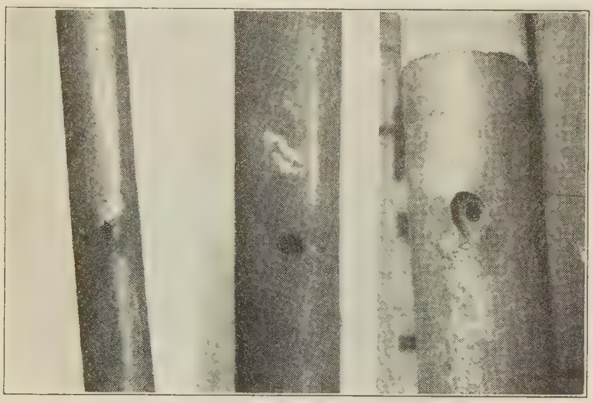
The chief results of tests of life duration of the cable under different vacua and voltages are given in Table I. On Figs. 5, 6, and 7 are drawn curves giving the life duration of the cable under different voltages in function of vacua, and the curves in Fig. 8 give the life duration under different vacua in function of the impressed voltage.

TABLE I

Voltage, kv. across 1 cm. of dielectric	Vacua in mm. of mercury column (under the atmospheric pressure)	Pressure in mm. of mercury column (over the atmospheric pressure)	Life duration in hours
60	..	250	10.5
60	0	0	5
60	100	..	5.2
60	200	..	4
60	300	..	2
50	100	..	13
50	200	..	21
50	300	..	11
42.6	100	..	36
42.6	200	..	57.7
42.6	300	..	41

The character of the places of breakdown of the cable is shown on Figs. 9, 10 and 11.

The study of curves on Figs. 5-8 shows the surprising fact that to each voltage corresponds a certain most advantageous vacuum, at which the life duration of a cable becomes a maximum, which is very sharply pronounced at voltages of 50 and 42.6 kv. and less sharply at a voltage of 60 kv. To check this fact, duplicate cables were tested and the results obtained showed a satisfactory agreement with the statement mentioned above. This would suggest the idea that this cannot be explained by lack of uniformity of the cable samples.



Figs. 9, 10, 11—Breakdown Points of Cable

In addition to this it may be seen from the curves on Figs. 5-8 that the vacuum for which the life duration of the cable has its greatest value depends upon the voltage. With increase of voltage the maximum becomes smoother and is displaced in the direction of lower vacua.

Dielectric Losses in the Insulation of the Cable in Function of the Internal Vacua in the Latter

In order to make a more complete analysis of the influence of vacua on life duration of the cable and to clear up the phenomenon of an optimum vacuum, measurements of loss angles were made at different voltages and for different vacua and pressures in the interior of the cable. The results of these measurements are given in curves of Figs. 12 and 13 which show the losses as functions of internal vacua and pressures.

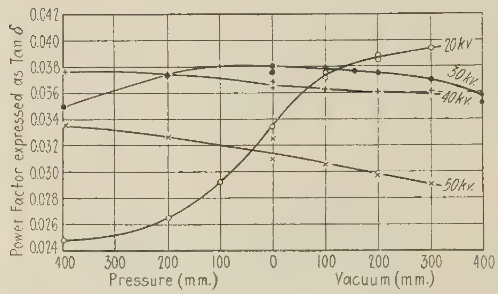


Fig. 12—Relation Between Power Factor and Internal Pressure

The vacua are drawn in the positive direction of the axis of abscissas and the pressures in the negative direction.

In Figs. 14 and 15 are drawn curves showing losses for different voltages as functions of different vacua and pressures. These losses are expressed as tangents of the imperfection angle δ of the dielectric. These are approximately equal to the cosines of the angle of lead for ordinary cable dielectrics such as those under consideration.

As we may see, with increase of voltage, $t\,g\,\delta$ increases, reaches a maximum value, and then decreases. The maximum of $t\,g\,\delta$ is reached at a lower voltage as the internal vacuum becomes greater. The variation of the value of $t\,g\,\delta$ is least in proximity to the maximum.

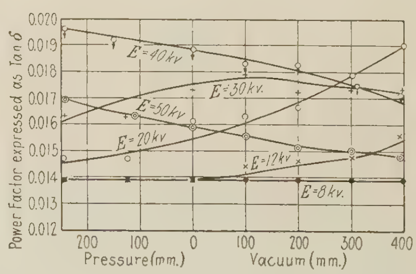


Fig. 13—Relation Between Power Factor and Internal Pressure

An explanation of the decrease of power factor with increase of voltage was given by C. L. Dawes and P. L. Hoover.[4] With an increase of voltage after all the air in the cable has been ionized, the potential

gradient in this air does not depend upon the voltage but equals the breakdown gradient of air. Hence it follows that the loss in air at any further increase of voltage will remain constant and the total loss in the cable will increase more slowly than in proportion to the square of voltage, *i. e.,* $t\,g\,\delta$ will decrease.

Assuming the loss angle of the dielectric proper (*i.e.,* without air) to have a constant value and neglecting the small variations of capacity of the cable at increase of voltage, it is possible to determine the loss angle of the entire insulation (*i. e.,* including air) for voltages higher than the voltage E_0, which corresponds to the maximum value of $t\,g\,\delta = t\,g\,\delta_0$, if we know the loss angle of the insulation proper, $t\,g\,\delta$.

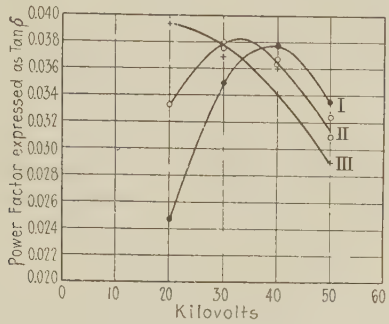


FIG. 14—RELATION BETWEEN POWER FACTOR AND INTERNAL PRESSURE

I. Pressure 400 mm. over atmosphere
II. Atmosphereic pressure
III. Vacuum 300 mm.

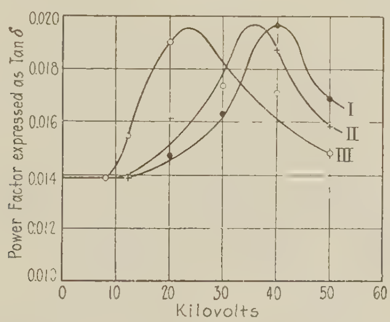


FIG. 15—RELATION BETWEEN POWER FACTOR AND VOLTAGE

I. Pressure 250 mm. over atmosphere
II. Atmospheric pressure
III. Vacuum, 400 mm.

In effect the loss in air for a voltage $E > E_0$ may be expressed as follows:

$$P_1 = E_0^2\, \omega\, C\, (t\,g\,\delta_0 - t\,g\,\delta_1) = \text{const.}$$

The loss in the insulation at a voltage E will be:

$$P_2 = E^2\, \omega\, C\, t\,g\,\delta_1$$

Therefore the total loss will be equal to:

$$P = P_1 + P_2$$

$$= E^2\, \omega\, C \left[\left(\frac{E_o}{E}\right)^2 (t\,g\,\delta_0 - t\,g\,\delta_1) + t\,g\,\delta_1\right] = E^2\, \omega\, C\, t\,g\,\delta$$

Thus

$$t\,g\,\delta = \left(\frac{E_o}{E}\right)^2 (t\,g\,\delta_0 - t\,g\,\delta_1) + t\,g\,\delta_1$$

The curve drawn on Fig. 16 gives the loss in the cable as a function of the applied voltage at atmospheric pressure. The dotted curve gives the values of $t\,g\,\delta$, as calculated from the above formula. As it may be seen, there it is fairly good agreement between the calculated and experimental curves.

The curves on Figs. 12 and 13 show that a certain vacuum at which the loss is a maximum corresponds to each voltage. After the maximum is attained the loss begins to decrease and the velocity of decrease of the loss at first is greater then at a further increase of the internal vacuum.

With increase of voltage, the maximum loss is displaced in the direction of small vacua and consequently we find displaced in the same direction the parts of curves with diminished loss variations. Thus we have a relation of the same character as that already mentioned, between the life of the cable and the internal vacua. This similarity shows that there is something in common between the two phenomena and suggests the ways for explanation of the nature of the phenomenon of the optimum life vacuum.

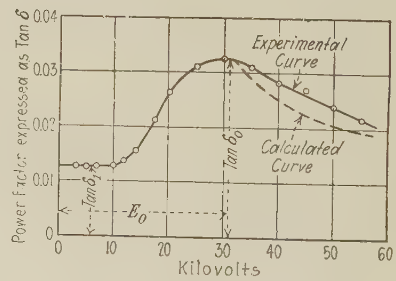


FIG. 16—COMPARISON OF CALCULATED AND EXPERIMENTAL CURVES BETWEEN POWER FACTOR AND VOLTAGE ABOVE THE VOLTAGE OF MAXIMUM POWER FACTOR

A complete explanation of this phenomenon was not yet found, but it is possible that its cause may be as follows.

With an increase of the internal vacuum in the cable at a constant voltage, (beginning from large pressures of the internal air at which the air is not yet wholly ionized), the loss will increase at first. Then with a vacuum, at which the internal air is wholly ionized, the loss will attain its maximum value. With a further increase of the internal vacuum the loss will decrease, as the dielectric strength of air will decrease and therefore the voltage drop across the air will also decrease. As the dielectric loss will heat the cable, the temperature

4. C. L. Dawes and P. L. Hoover, *Ionization Studies in Paper Insulated Cables,* A. I. E. E. TRANS., Vol. 45, 1926, p. 141.

of the latter will vary approximately in the same manner as its dielectric loss.

As the life duration of a cable must naturally decrease with an increase of hot-spot temperature, it should at first decrease with an increase of the vacuum, and then increase. With increase of the vacuum, however, because of the decrease of voltage drop through the air, the gradient of the electric field in the insulation of the cable must increase. In the same way, the tangential components of the gradient along the joints of paper strips of insulation must also increase. All these causes provoke a continual decrease of the life duration of a cable with increase of the vacuum. For instance the fact that the life duration becomes five times less, at a voltage of 60 kv. with a change of conditions of the internal air in the cable from a pressure of 250 mm. (over atmospheric pressure) to a vacuum of 300 mm., suggests that in general the dielectric strength of a solid insulation may depend upon the pressure of the surrounding air. In a cable it is quite possible that the barrier or baffle properties of the insulating paper become inferior and a freer motion of ions begins in the latter.

Thus we see that with an increase of vacuum, at first all causes tend to provoke a decrease in the life of the cable. Then, when the loss and consequently the temperature begin to decrease, their influence may

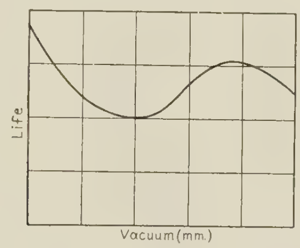


Fig. 17—Typical Life-Vacuum Curve as Suggested by Power Factor and Vacuum Relation

become predominant in comparison with all other causes and the cable's life will begin to increase. With a further increase of vacuum, the rate of variation of losses, as stated above, will diminish. This will lead to a state when the influence of causes decreasing the cable's life will predominate.

This analysis shows that the curve giving the influence of the vacuum on a cable's life duration must be of *s* shape shown in Fig. 17. This curve has the same shape as that obtained by experiment for a voltage of 60 kv. and reproduced in Fig. 5. For the other two experimental curves drawn on Figs. 6 and 7, we have only the parts containing the maximum, as these were not determined over a wide range of pressures. The fact that the maximum becomes smoother with an increase of voltage can be explained in the following way; at high voltages, the gradient in the insulation of the cable and the tangential components of the gradient become of prevailing importance, for, at high voltages, when the air is wholly ionized, the losses decrease with an increase of vacuum and the influence of their decrease at an increase of the vacuum becomes less perceptible.

At the working voltage of the cable, the optimum vacuum as it appears will be so considerable that it will be practically necessary to take into consideration only the decrease of the cable's life.

The Appearance of Internal Vacua in Cable in Consequence of Chemical and Thermal Alterations

It has been mentioned that during the tests for determining the life duration of the cable in function of internal vacua, a tendency to an automatic increase

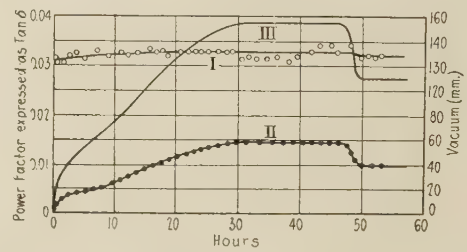


Fig. 18—Change of Vacuum and Power Factor as Result of Prolonged Life Test

I. Power factor
II. Observed Vacua
III. Vacua corrected for parasitical volumes

of the vacuum was observed, as it seems under the influence of chemical alterations in the impregnating compound under the influence of ionized air.

To study this phenomenon quantitatively, a piece of cable was put under atmospheric pressure of air on its working voltage of 20.2 kv. A manometer was connected to one of the extremities of the cable to observe the appearance of the internal vacua. The other extremity of the cable was hermetically closed. At the same time, loss measurements were undertaken. The curves in Fig. 18 reproduce the results of the experiment. The curves are: I, the loss curve; II, the curve of observed vacua, and III, the curve of vacua, which would happen if there would not be connected to the cable the parasitical volume of air in the leads of rubber tubes and in the manometer.

The sudden decrease of vacuum at the end of the experiment can be explained by imperfect sealing of the cable.

The volume of air, which it was necessary to know to plot curve III, was measured by applying to the interior of the cable, a known volume of air at atmospheric pressure and observing the change of the vacuum after its introduction into the cable.

It is obvious from curve III that under the working voltage of the cable, vacua approximating 155 mm. of mercury may appear.

For the determination of internal vacua which can appear under the influence of temperature changes, a piece of cable was heated to a temperature about 40 deg. cent., measured by a thermometer dropped to the core of the cable.

The cable was heated with an electric current about 800 amperes. After the heating current was interrupted, in a lapse of time, which allowed to attain a comparatively uniform distribution of temperatures in the interior of the cable, the latter was hermetically closed and connected to a manometer.

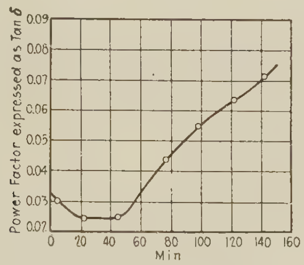


Fig. 19—Relation Between Power Factor and Life on a Cable which Failed in 157 Min.

In this way it was found that at a decrease of temperature in the cable of 25 deg. cent. the internal vacuum increased to 180 mm. of mercury (corrected for the parasitical volume in leads of rubber tubes and the manometer).

Losses in Cable as Function of the Duration of Voltage Application

Loss measurements in the cable were made at the same time as life duration of the cable as a function of the internal vacua was determined.

Characteristic curves of power factor as function of applied voltage obtained during these tests are reproduced in Figs. 19 and 20. As may be seen from these curves, $tg\,\delta$ at first diminishes, then remains constant for a time and then increases until breakdown of the cable occurs.

The decrease of $tg\,\delta$ during a certain time after the application of voltage may be explained by the heating of the cable through the dielectric losses. The ambient temperature was about 15 deg. cent. and as the cable losses have a minimum at a temperature about 40 deg. cent., as shown by Mr. P. Dunsheath,[5] the heating of the cable leads to a decrease of $tg\,\delta$. After establishing a thermal equilibrium, $tg\,\delta$ remains constant for a certain period. This shows that the chief causes of the breakdown in the cable are chemical alterations, not pyroelectric effects.

If breakdown in the cable were due to thermal causes, we should have a continual rise of temperature in the cable and the loss curve would not have its horizontal part. The pyroelectric effect begins to play an important part only at the approach of the cable's breakdown, which accounts for the appearance of hot spots before the breakdown.

5. P. Dunsheath, "Dielectric Problems in High-Voltage Cables," *Journal* of the Institution of Electrical Engineers, January, 1926.

Conclusions

1. Internal vacua of the order of 350-400 mm. of mercury may appear in a cable under the influence of temperature changes and ionization of air.

2. The appearance of internal vacua at the working voltage of a cable may noticeably lower the life duration of the latter.

3. Air can easily propagate along the core of a cable and in the interior of the latter, but on considerable lengths of cable stoppers may occur, which will impede such a propagation.

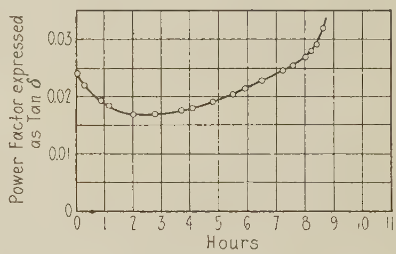


Fig. 20—Relation Between Power Factor and Life on a Cable which failed in 10 hr. 29 min.

4. To prevent the dangerous effect of internal vacua the following measures may be recommended:

a. Use of chemically stable compounds;

b. Arrangement of free ducts in the interior of the cable for air to maintain the atmospheric pressure in in the interior of the cable by using the flow of air from the extremities of the cable;

c. Arrangement of free air ducts in the interior of the cable and in the splices for compensation of vacua that may appear with the volume of air contained in them;

d. Pumping of dry air through ducts in the core of a cable to maintain the pressure in the cable higher than that of the atmosphere;

e. Filling a cable with transformer oil forced under pressure at the splices of a cable to provide compensation at volume changes of internal air in the cable.

WILL TAKE DISTRIBUTION CENSUS FOR 1930

The fifteenth decennial census which will be taken in 1930 will probably include a national survey of distribution, according to a recent statement by Secretary of Commerce, Herbert Hoover. It is stated that details of the national census remain to be worked out but that the need for statistical information relating to the distribution of commodities has long been felt. A census of production is well organized but a census of distribution must be put on the basis of an actual enumeration.

Approximate Solution for Electrical Networks

When These are Highly Oscillatory

BY E. A. GUILLEMIN[1]

Associate, A. I. E. E.

Synopsis.—*The general solution to the slightly damped network is expressed in terms of the undamped solution by means of series expansions. The first part of the paper gives a method for evaluating the complex roots of the determinantal equation, and the second part shows how the expansions of the first part may be correlated with the Heaviside formula to form the complete approximate solution. An example illustrates the application to a simple network.*

In working out the general solution of an electrical network, subjected to suddenly applied e. m. fs., by the classical method, there are two steps which involve a disagreeable amount of calculation—the determination of the natural angular velocities of the system, and the evaluation of integration constants or transient current amplitudes. The use of Heaviside's expansion formula does considerable toward simplifying—at least systematizing—the latter; but there still remains the necessity of solving high powered algebraic equations, which, when the network contains more than two meshes, becomes a tedious process. Primary among the factors which contribute toward the unwieldiness of the solution are the dissipative terms introduced by the presence of ohmic resistances. The solution for an idealized system with no ohmic losses is much simpler both analytically and in consequent numerical manipulation. In the first place, the determinantal equation for this case contains only even powers of the independent variable, say p, and, when solved for p^2, contains only negative real roots which may be evaluated by Newton's or Lagrange's approximation methods when the degree is above the third in p^2. Secondly, only purely imaginary or purely real quantities enter into the manipulations involved in evaluating integration constants instead of complex quantities. As soon as resistance enters into the problem, and in actual cases it always does, the work increases manifold. In practise, however, it is very frequently the case that although resistances are present, they are very small and cause only a relatively slow attenuation. We call such circuits "highly oscillatory." Practically every network used in connection with radio telephony comes under this head. It would seem, therefore, both useful and very logical to approach this case from the standpoint of the perturbation problem, and consider the slightly damped network as perturbed out of its undamped condition. It is the object of this paper to show how, by means of expansion in series, this standpoint may be carried out. The same idea may be applied to the distributed constant problem and many others; and it is hoped that interest might be stimulated in this general direction.

If we consider the meshes in our electrical network numbered from 1 to n, and let λ_{ii}, ρ_{ii}, σ_{ii} be the total inductance, resistance, and elastance, respectively, in mesh i, and further let $-\lambda_{ik}$, $-\rho_{ik}$, $-\sigma_{ik}$ be the total inductance, resistance, and elastance, respectively, common to meshes i and k (λ_{ik} being the sum of mutual and common self inductances), then the system of homogeneous differential equations describing the natural mode of oscillation of the system, when written for the mesh charges, takes the form:[2]

$$\left.\begin{array}{l} a_{11}\,x_1 + a_{12}\,x_2 + \;.\;.\;.\;.\; + a_{1n}\,x_n = 0 \\ a_{21}\,x_1 + a_{22}\,x_2 + \;.\;.\;.\;.\; + a_{2n}\,x_n = 0 \\ .\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;. \\ a_{n1}\,x_1 + a_{n2}\,x_2 + \;.\;.\;.\;.\; + a_{nn}\,x_n = 0 \end{array}\right\} \qquad (1)$$

$$\left.\begin{array}{ll} \text{with} & a_{ik} = \lambda_{ik}\dfrac{d^2}{d\,t^2} + \rho_{ik}\dfrac{d}{d\,t} + \sigma_{ik} \\ \text{and} & x_k = \displaystyle\int_0^t i_k\,d\,t \end{array}\right\} \qquad (2)$$

The use of mesh charges x_k instead of mesh currents i_k avoids the appearance of integrals in the system (**1**) and also brings out a closer analogy between the electrical system and the equivalent mechanical system in which displacements take the place of electrical charges. If we assume as solutions to system (**1**) the normal functions:

$$x_k = X_k\,\epsilon^{pt} \qquad (3)$$

there results the system of simultaneous homogeneous algebraic equations:

$$\left.\begin{array}{l} b_{11}\,X_1 + b_{12}\,X_2 + \;.\;.\;.\;.\; + b_{1n}\,X_n = 0 \\ b_{21}\,X_1 + b_{22}\,X_2 + \;.\;.\;.\;.\; + b_{2n}\,X_n = 0 \\ .\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;. \\ b_{n1}\,X_1 + b_{n1}\,X_2 + \;.\;.\;.\;.\; + b_n\,X_n = 0 \end{array}\right\} \qquad (4)$$

$$\text{where:}\quad b_{ik} = b_{ik}\,(p) = \lambda_{ik}\,p^2 + \rho_{ik}\,p + \sigma_{ik} \qquad (5)$$

The assumptions (**3**) will be useful if system (**4**) leads

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 13-17, 1928.

2. See Carson's "Electric Circuit Theory and Operational Calculus," McGraw-Hill, 1926. Our system of equations (**1**) is identical with Carson's system (**14**), p. 10, with the substitution: $i_k = \dfrac{d\,x_k}{d\,t}$, allowing for differences of notation, of course. Our following equations (**4**) and (**6**) correspond in the same way to Carson's equations (**15**) and (**16**), pp. 10 and 11.

to non-trivial solutions for the amplitudes X_k. This will be the case if the determinant of the system vanishes, *i. e.*, if:

$$D(p) = \begin{vmatrix} b_{11} & \dots & b_{1n} \\ b_{21} & \dots & b_{2n} \\ \dots & \dots & \dots \\ b_{n1} & \dots & b_{nn} \end{vmatrix} = 0 \qquad (6)$$

For the solution to be unique it is further necessary that D have the rank $n - 1$, *i.e.*, that at least one of its first minors shall not vanish. Equation (6) is in compact form the determinantal equation of the oscillatory system. Since each element is in general a polynomial of the second degree in p, D will be a polynomial of the 2 nth degree in p, and according to the fundamental law of Algebra (6) can be satisfied in 2 n ways. Hence 2 n solutions (3) exist with 2 n arbitrary amplitudes X_k to satisfy the 2 n initial charges and currents in the given electrical system.

Consistent with our major premise, we proceed to expand (6) in powers of ρ_{ik} by Taylor's theorem. We have:[3]

$$D(p) = \Big[D(p) \Big]_{\rho_{ik}=0} + \frac{1}{1!} \sum_{1}^{n}{}^{ik} \left[\frac{\partial D(p)}{\partial \rho_{ik}} \right]_{\rho_{ik}=0} . \rho_{ik} + \dots \qquad (7)$$

But according to the rule for differentiating determinants:[4]

$$\frac{\partial D(p)}{\partial \rho_{ik}} = \frac{\partial D(p)}{\partial b_{ik}} \frac{\partial b_{ik}}{\partial \rho_{ik}} = B_{ik}(p) \frac{\partial b_{ik}}{\partial \rho_{ik}}$$
$$= B_{ik}(p) . p \qquad (8)$$

where $B_{ik}(p)$ is the minor of b_{ik} in (6). Since $D(p)$ is a whole rational function in ρ_{ik}, the expansion (7) will contain a finite number of terms. From (8) it is evident[5] that successive terms will rapidly become smaller if $\rho_{ik} << p$. We will assume this and consequently neglect all powers of the ρ_{ik}'s above the first. If now we adopt the notation:

$$\left.\begin{aligned} \Big[D(p) \Big]_{\rho_{ik}=0} &= D^*(p) \\ \text{and} \quad \Big[B_{ik}(p) \Big]_{\rho_{ik}=0} &= B_{ik}^*(p) \end{aligned}\right\} \qquad (9)$$

our determinantal equation (6) becomes:

$$D(p) = D^*(p) + p \sum_{1}^{n}{}^{ik} B_{ik}^*(p) . \rho_{ik} = 0 \qquad (10)$$

A first approximation to the roots of (10) is given by:

$$D^*(p) = 0 \qquad (11)$$

which is the determinantal equation for neglected attenuation. As already pointed out, it contains only even powers of p, the roots for p^2 being negative real, and hence those for p purely imaginary. Let the roots of (11) be given by:

$$p = p^* \qquad (12)$$

According to the Newtonian method[6] we then put for the roots of $D(p)$:

$$p = p^* + \delta \qquad (13)$$

and substitute this value into $D^*(p)$ of equation (10). For the second term in (10) it is sufficient to substitute (12). We then have:

$$D(p) = D^*(p^* + \delta) + p^* \sum_{1}^{n}{}^{ik} B_{ik}^*(p^*) . \rho_{ik} = 0 \quad (14)$$

Expanding the first term in a Taylor's series about $p = p^*$ we get:

$$D^*(p^* + \delta) = D^*(p^*) + \frac{1}{1!}\left(\frac{\partial D^*}{\partial p}\right)_{p=p^*} . \delta + \dots \quad (15)$$

Now if we note that

$$\begin{aligned} D^*(p) &= C_n p^n + C_{n-2} p^{n-2} + \dots + C_0 \\ &= C_n (p^* + \delta)^n + C_{n-2} (p^* + \delta)^{n-2} + \dots + C_0 \end{aligned}$$

and $(p^* + \delta)^n$

$$= p^{*n} \left\{ 1 + \frac{n}{1!} \frac{\delta}{p^*} + \frac{n(n-1)}{2!} \left(\frac{\delta}{p^*}\right)^2 + \dots \right\}$$

we see that terms of (15) above the first degree in δ may be neglected if:

$$\frac{n-1}{2} \frac{\delta}{p^*} << 1 \qquad (16)$$

which is the criterion for a "highly oscillatory" network in the sense in which that term is used in this paper. Substituting (15) into (14) and noting that:

$$D^*(p^*) = 0,$$

and also that

$$\left[\frac{\partial D^*}{\partial p}\right]_{p=p^*} = \sum_{1}^{n}{}^{ik} \left[\frac{\partial D^*}{\partial b_{ik}} \frac{\partial b_{ik}}{\partial p} \right]_{p=p^*}$$
$$= \sum_{1}^{n}{}^{ik} 2\, \lambda_{ik}\, p^* B_{ik}^*(p^*) \qquad (17)$$

we get $\delta \sum_{1}^{n}{}^{ik} 2\, \lambda_{ik} B_{ik}^*(p^*) + \sum_{1}^{n}{}^{ik} \rho_{ik} B_{ik}^*(p^*) = 0$

3. See Wood's "Advanced Calculus," Ginn & Co., 1926, p. 49, equation (1), or any similar text covering Taylor's theorem.

4. See, for example, R. F. Scott's "Theory of Determinants," Cambridge University Press, 1880, p. 35.

5. This will be clear if we note that B_{ik} is two powers lower in p than D. Hence the second term of (7) divided by the first will be of the order: ρ_{ik}/p.

6. See, for example, Woods & Bailey, "A Course in Mathematics," Ginn & Co., 1907, p. 114. The method is there shown applied to the solution of numerical equations, but the general idea involved is the same as that used in this paper.

$$\text{or } \delta = -\frac{\sum_1^n {}^{ik} \rho_{ik} B_{ik}^* (p^*)}{\sum_1^n {}^{ik} 2 \lambda_{ik} B_{ik}^* (p^*)} \qquad (18)$$

From the form of (18) it is clear that δ will always be real, and hence represents the damping factor associated with the frequency given by p^*. The complete complex "natural angular velocity" so called is given by (13). The form of (18) is in itself interesting. The damping factors appear as the negative quotient of the averaged mesh resistances weighted by the unperturbed minors, and double the mesh inductances averaged in the same way. The dimension of δ and its similarity to that for the simple R, L, C circuit are evident. The latter may serve as a simple illustration of our result. Here,

$$D(p) = b(p) = L p^2 + R p + \frac{1}{C} = 0.$$

$$D^*(p) = L p^2 + \frac{1}{C} = 0; \; p^* = \frac{\pm j}{\sqrt{LC}}.$$

The B_{ik}^* are unity in this case and we have,

$$\delta = -\frac{R}{2L},$$

$$\text{and hence, } p = -\frac{R}{2L} \pm j \frac{1}{\sqrt{LC}}.$$

The exact root differs from this only in that the damped angular frequency,

$$\pm j \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

appears in place of the undamped.

Although equation (18) is applicable more directly to the mathematical representation of the network itself, the same idea can be carried out on the determinantal equation in its polynomial form. If we have given:

$$D(p) = A_n p^n + A_{n-1} p^{n-1} + \ldots + A_0 = 0 \qquad (19)$$

it can easily be shown that the corresponding determinantal equation for the undamped case is approximately[7] given by simply striking the second, fourth, etc., terms, *i. e.*, that:

$$D^*(p) = A_n p^n + A_{n-2} p^{n-2} + \ldots + A_0 = 0. \qquad (20)$$

Then if we let,

$$G(p) = A_{n-1} p^{n-1} + A_{n-3} p^{n-3} + \ldots + A_1 p \qquad (21)$$

$$\text{it will be seen that, } \Big[G(p) \Big]_{\rho_{ik}=0} = 0,$$

and hence that (21) can take the place of the double sum in (7). Applying the Newtonian method as before we find:

$$\delta = -\frac{G(p^*)}{\left(\frac{\partial D^*}{\partial p}\right)_{p=p^*}} \qquad (22)$$

To illustrate the application of (22), let us consider the numerical quartic:

$$D(p) = p^4 + 50 p^3 + 8.91 \times 10^5 p^2 + 2.03 \cdot 10^7 p + 1.601 \cdot 10_n = 0$$

Here $D^*(p) = p^4 + 8.91 \cdot 10^5 p^2 + 1.601 \cdot 10^{11} = 0$

and $p^* = \pm j\, 800$ and $\pm j\, 500$.

For the first of these:

$$G(p^*) = \mp j\, 9.36 \cdot 10^9; \left(\frac{\partial D^*}{\partial p}\right)_{p=p^*} = \mp j\, 6.23 \cdot 10^8$$

and hence $\delta = -15$.

For the second:

$$G(p^*) = \pm j\, 3.90 \cdot 10^9; \left(\frac{\partial D^*}{\partial p}\right)_{p=p^*} = \pm j\, 3.90 \cdot 10^8,$$

and hence $\delta = -10$.

The final roots are:

$$-10 \pm j\, 500 \text{ and } -15 \pm j\, 800$$

which are exactly the ones used in making up the above equation, the differences due to the approximate method of solution not being noticeable on the slide rule used in the calculation.

It frequently happens that due to the absence of independent inductance or elastance in one of the meshes, the determinantal equation comes out to be of an odd degree. The number of natural angular frequencies contained in the system in that case will be $\frac{n-1}{2}$ where n is the degree of the equation. The odd root will be purely real. The fact that it possesses a normal coordinate[8] as well as the rest of the frequencies but vanishes for vanishing resistances, seems to indicate physically that in the latter case a regrouping of the meshes can be carried out so as to reduce their number by one—there being always as many normal coordinates as there are meshes, (physical dimensions in the equivalent mechanical system). It would seem as though for this real root our method would fail, since its imaginary part is zero. However it can be shown that so long as this real root is within the same order of magnitude as the real portions of the rest of the roots, the method still holds with fair accuracy. Let us suppose we have an equation of even degree given by:

$$D(p) = 0;$$

7. For the preceding simple example this happens to be exact; but in general the resistance terms will contribute a small share to the coefficients of even powers of p.

8. See paper by the writer entitled "Making Normal Coordinates Coincide with the Meshes of an Electrical Network," *Proceedings* of the I. R. E., Nov. 1927, p. 935.

and we introduce an extra real root $p = -\alpha$. Then the equation of odd degree becomes:

$$D_0(p) = (p + \alpha) D(p) = 0. \qquad (23)$$

The equation for neglected resistance would then be:

$$D_0^*(p) = p D^*(p) = 0,$$

which contains the zero root mentioned above. Hence, substituting $p = 0 + \delta$ into (23) and expanding we get:

$$D_0(\delta) = D_0(0) + \frac{1}{1!}\left(\frac{\partial D_0}{\partial p}\right)_{p=0} \cdot\cdot + \ldots = 0,$$

$$\text{and} \qquad \delta = -\frac{D_0(0)}{\left(\frac{\partial D_0}{\partial p}\right)_{p=0}}.$$

But: $\qquad D_0(0) = \alpha D(0),$

$$\text{and} \qquad \left(\frac{\partial D_0}{\partial p}\right)_{p=0} = \alpha\left(\frac{\partial D}{\partial p}\right)_{p=0} + D(0),$$

$$\text{so that:} \quad \delta = -\frac{\alpha D(0)}{D(0) + \alpha\left(\frac{\partial D}{\partial p}\right)_{p=0}},$$

from which it is clear that the method still gives satisfactory results if:

$$\alpha\left(\frac{\partial D}{\partial p}\right)_{p=0.} << D(0);$$

or by using the notation of equation (19), if:

$$\alpha << \frac{a_0}{a_1}.$$

In our numerical example above, this means that an additional real root $(p + \alpha)$ may be introduced and re-evaluated by formula (22) with good results as long as

$$\alpha << \frac{1.601 \cdot 10^{11}}{2.03 \cdot 10^{7}} = 7890,$$

which condition is easily fulfilled if α is not much larger than the real portions of the other roots. Note that for the evaluation of this real root equation (22) simply becomes equal to the negative quotient of the last two coefficients of the odd powered determinantal equation in the form of (19). After this odd root has thus been determined, it is best to divide it out and then treat the remainder as in the case where $D(p)$ is of even degree. To illustrate let us take our previous numerical example, and introduce the root $p = -100$. It then becomes:

$$D(p) = p^5 + 150\,p^4 + 8.96 \cdot 10^5\,p^3 + 1.094 \cdot 10^8\,p^2 + 1.62 \cdot 10^{11}\,p + 1.601 \cdot 10^{13} = 0.$$

Here: $\quad D^*(p) = p^5 + 8.96 \cdot 10^5\,p^3 + 1.62 \cdot 10^{11}\,p,$

and $\quad G(p) = 150\,p^4 + 1.094 \cdot 10^8\,p^2 + 1.601 \cdot 10^{13}.$

By applying (22) for $p^* = 0$ we get:

$$\delta = -\frac{1.601 \cdot 10^{13}}{1.62 \cdot 10^{11}} = -98.8$$

which is the root correct to within 0.2 per cent.

Our next step is to show how nicely the above method of arriving at the approximate complex roots fits in with an approximate determination of the transient current amplitudes by means of Heaviside's well-known expansion formula. The latter may be put into the form:[9]

$$i_{ik} = E \sum\nolimits^{\nu} \frac{B_{ik}(p_\nu)\,\epsilon^{p_\nu t}}{\left(\frac{\partial D}{\partial p}\right)_{p=p_\nu*}} \qquad (24)$$

when written for the current in mesh i due to a suddenly applied direct voltage E in mesh k or vice versa. $D(p)$ is the determinant given by (6), and B_{ik} the respective minor of this determinant. The summation is to extend over all the roots of the determinantal equation:

$$D(p) = 0.$$

For the case of slight damping, however, the solution is given approximately by:

$$i_{ik} = E \sum\nolimits^{\nu} \frac{B_{ik}^*(p_\nu^*)\,\epsilon^{p_\nu t}}{\left(\frac{\partial D^*}{\partial p}\right)_{p=p_\nu*}}. \qquad (25)$$

But the denominators in this sum are already known from equation (17), so that we merely have to substitute these same values into (25) in order to get the complete solution. The approximate solution to the determinantal equation dovetails nicely with the process of evaluation of the transient current amplitudes. Substituting (17) into (25), we can write for Heaviside's expansion formula in approximate form:

$$i_{ik} = \frac{E}{2} \sum\nolimits^{\nu} \frac{B_{ik}^*(p_\nu^*)\,\epsilon^{p_\nu}{}_t}{p_\nu^* \sum_{1}^{n}{}^{ik} \lambda_{ik}\,B_{ik}^*(p_\nu^*)} \qquad (26)$$

If the determinantal equation (6) has no zero root, it means that the mesh in which the e. m. f. is impressed contains a condenser so that the steady state becomes

9. It will be seen with a little investigation that our:

$$\frac{D(p)}{B(p)} = p\,Z(p)$$

where $Z(p)$ is the transient impedance as usually defined in connection with Heaviside's expansion formula. Now:

$$\frac{d}{dp}\left[\frac{D}{B}\right]_{p=p\nu} = \left[\frac{B \cdot \frac{dD}{dp} - D\frac{dB}{dp}}{B^2}\right]_{p=p\nu} = \frac{\left(\frac{dD}{dp}\right)_{p=p\nu}}{B(p^\nu)}$$

$$= \left[p\frac{dZ}{dp} + Z\right]_{p=p\nu} = p^\nu\left(\frac{dZ}{dp}\right)_{p=p\nu} + Z(p^\nu).$$

Comparing with the usual form of Heaviside's formula, the form (24) will be seen to be identical with it. For additional information on this point, see "Notes on Operational Calculus," by V. Bush, obtainable from the Electrical Engineering Dept. of the Massachusetts Institute of Technology, Cambridge, Mass.

zero. Since the terms in (**26**) are conjugate pairs, the current will be twice the real portion, or:

$$i_{ik} = E \sum_{1,3,5..}^{n} {}_{\nu} \frac{B_{ik}^* (p_\nu^*) \, \epsilon^{\delta t}}{| p_\nu^* | \sum_{1}^{n} {}_{ik} \lambda_{ik} B_{ik}^* (p_\nu^*)} \sin | p_\nu^* I t | \quad (\mathbf{27})$$

In order to illustrate the entire process of solution outlined in this paper, let us consider a simple network consisting of two inductively coupled meshes with a suddenly applied constant potential of E volts in the first,—the circuit constants being given by:

$\lambda_{11} = 0.3$ henries; $\lambda_{12} = -.1$ henries; $\lambda_{22} = 0.2$ henries.

$\rho_{11} = 5$ ohms; $\rho_{12} = 0$; $\rho_{22} = 5$ ohms.

$\sigma_{11} = 10^6$ darafs; $\sigma_{12} = 0$; $\sigma_{22} = 10^8$ darafs.

Then,

$$D^* (p) = \begin{vmatrix} .3\, p^2 + 10^6 & -.1\, p^2 \\ -.1\, p^2 & .2\, p^2 + 10^8 \end{vmatrix}$$

$$= p^4 + 6.04 \cdot 10^8 \, p^2 + 2 \cdot 10^{15} = 0.$$

From which $p_{1,2}^* = \pm j\, 2.45 \cdot 10^4$; $p_{3,4}^* = \pm j\, 1.87 \cdot 10^3$.

We then find

$B_{11}^*(p_{1,2}^*) = -2 \cdot 10^7$; $B_{12}^*(p_{1,2}^*) = -6 \cdot 10^7$; $B_{22}^* (p_{1,2}^*) = -1.79 \cdot 10^8$.

and $B_{11}^* (p_{3,4}^*) = 9.93 \cdot 10^7$; $B_{12}^* (p_{3,4}^*) = -3.5 \cdot 10^5$; $B_{22}^* (p_{3,4}^*) = -5 \cdot 10^4$.

From which $\sum_{1}^{n} {}_{ik} \rho_{ik} B_{ik}^* (p_{1,2}^*) = -9.95 \cdot 10^8$;

$$\sum_{1}^{n} {}_{ik} \rho_{ik} B_{ik}^* (p_{3,4}^*) = 4.965 \cdot 10^8,$$

and $\sum_{1}^{n} {}_{ik} 2\, \lambda_{ik} B_{ik}^* (p_{1,2}^*) = -5.96 \cdot 10^7$;

$$\sum_{1}^{n} {}_{ik} 2\, \lambda_{ik} B_{ik}^* (p_{3,4}^*) = 5.97 \cdot 10^7.$$

and substituting into (**18**) we have:

$$\delta_{1,2} = - \frac{9.95 \cdot 10^8}{5.96 \cdot 10^7} = -16.7$$

$$\delta_{3,4} = - \frac{4.96 \cdot 10}{5.97 \cdot 10^7} = -8.33$$

Then substituting into (**27**) we get for the current in mesh one:

$$i_{11} = E\, (2.74 \cdot 10^{-5}\, \epsilon^{-16.7 t} \sin 24500\, t + 1.78 \cdot 10^{-3}\, \epsilon^{-8.33 t} \sin 1870\, t).$$

The current in mesh two is found from this by simply multiplying the first term by $\dfrac{B_{12}^* (p_{1,2}^*)}{B_{11}^* (p_{1,2}^*)}$,

and the second by $\dfrac{B_{12}^* (p_{3,4}^*)}{B_{11}^* (p_{3,4}^*)}$.

We find $i_{12} = E\, (8.22 \cdot 10^{-5}\, \epsilon^{-16.7 t} \sin 24500\, t - 6.28 \cdot 10^{-6}\, \epsilon^{-8.33 t} \sin 1870\, t)$.

It is quite apparent that the saving in tedious manipulation over the usual method is considerable.

LUMBER WASTE WARNING SOUNDED

A recent statement attributed to an important lumber manufacturers' association which is said to imply that there is no danger of a timber shortage, has brought a warning from the Chief of the U. S. Forest Service, Col. W. B. Greeley. He shows that his office has made investigations indicating that our timber supply is being used up much faster than it is being replaced by new growth and that most of our timber still comes from the diminishing virgin forests.

The greatest evil of the present forest situation is the large and increasing amount of cut-over land that is no longer growing timber, says the Forest Service statement, and no better contribution can be made to a solution of the forest problem than acceptance by the lumber industry of responsibility for reforesting their own lands.

It has never been his view, Colonel Greeley said, that forest conservation ought to be accomplished by restricting the use of wood. On the contrary, he hopes to see a wide and liberal use of wood continued in the country, thereby promoting industry and commerce and encouraging the profitable use of vast areas of otherwise waste land.

The association in return states that it is in substantial accord with Col. Greeley's views that reforestation is essential to the maintenance of an abundant supply of forest products, but also asserts that the more wood used the greater will be the incentive to grow wood.

WILL STUDY TRANSPORT FACILITIES OF MISSISSIPPI

The Transport Division of the Department of Commerce has announced that it has assembled a field staff in its branch office in St. Louis for the purpose of studying inland and waterway facilities on the Mississippi and Warrior Rivers. The survey of available traffic is being made upon the request of Secretary of War, Davis, who made the request for such a survey in his recent report.

Mr. M. R. Beaman, of the South Jersey Port Commission, will direct the field work. He has been granted a leave of absence for this purpose.

It was stated by the Secretary of War, in requesting this survey, that present facilities were not enough to handle the amount of shipping on these rivers and it is understood that the study is being made preparatory to seeking an authorization from Congress for an increase in the capital stock of the barge line from $5,000,000 to $50,000,000. This would permit expansion of the service to other tributaries of the Mississippi.

The Boltzmann-Hopkinson Principle of Superposition as Applied to Dielectrics

BY F. D. MURNAGHAN[1]

Non-member

Synopsis.—*The principle of superposition, discussed first for dielectrics by Hopkinson, has been shown for a long time in experiment. However, its validity for the several theories which have been advanced for dielectric behavior has been shown in only a few cases. One of the exceptions is the important theory of Maxwell.*[2] *This paper shows that the principle of superposition is a necessary consequence of Maxwell's theory. It goes somewhat further and shows that the principle is valid for any theory which leads to a system of linear differential equations with constant coefficients.*

* * * * *

If we have a plane layer dielectric with n layers and denote the thickness of the rth layer by a_r, its specific inductive capacity by K_r and its specific resistance by r_r then the common current density u in each layer is given by

$$u = (D + b_r) f_r \tag{1}$$

when D denotes time differentiation,[3] f_r stands for the displacement in the rth layer, and b_r is an abbreviation for the ratio $4\,\pi/K_r\,r_r$. Furthermore, the displacements f are connected with the applied e. m. f. E by the equation

$$\alpha_1 f_1 + \alpha_2 f_2 + \ldots + \alpha_n f_n = E \tag{2}$$

where α_r is an abbreviation for the ratio $4\,\pi\,a_r/K_r$. These equations lead to a linear differential equation of order $n-1$ for each of the displacements f, the equation satisfied by f_r, being

$$\left[\frac{\alpha_1}{D + b_1} + \frac{\alpha_2}{D + b_2} \ldots + \frac{\alpha_n}{D + b_n}\right] f_r = \frac{E}{D + b_r} \tag{3}$$

it being understood, however, that this is merely a convenient way of writing the differential equation which results when both sides are cleared of fractions by multiplying through by the product of all the denominators $(D + b_r)$. The dielectric being supposed initially uncharged we have to find solutions of (3), consistent with (1), which have all the same value $E(0)/\alpha_1 + \ldots + \alpha_n)$ when $t = 0$.

The differential equation (3) has on the left hand side a differential expression $F(D)$ of order $n-1$, the coefficient of the highest order derivative D^{n-1} being $(\alpha_1 + \alpha_2 + \ldots + \alpha_n)$, and we shall denote this coefficient by A, for convenience. The right hand side of (3) is the result of differentiating the function E of t in the manner indicated by the product of all the $(D + b)$ save the single one $(D + b_r)$. It will be convenient first to consider the auxiliary equation

$$F(D)\, y = E(t) \tag{4}$$

since if we have a solution y of this equation the function f_r obtained by operating on y by the product of all the $(D + b)$ save the single one $(D + b_r)$ will satisfy the equation (3). In fact since the coefficients in the polynominal $F(D)$ are constants we may interchange the order of the differentiations indicated by $F(D)$ and by the product of the factors $(D + b)$, Hence

$$\begin{aligned} F(D)\ .\ (D + b_1)(\ .\ .\ .\ )(D + b_n)\, y \\ = (D + b_1)(.\ .\ .)(D + b_n)\ .\ F(D)\, y \\ = (D + b_1)(.\ .\ .)(D + b_n)\, E(t) \end{aligned}$$

We now proceed to find, by a method due to Cauchy, that particular solution of the equation (4) which vanishes, together with all its derivatives up to the $n-2$nd inclusive when $t = 0$. The homogeneous equation corresponding to (4), *i. e.*,

$$F(D)\, z = 0 \tag{5}$$

being of order $n-1$, has $n-1$ distinct solutions which we may denote by $(z_1, z_2, \ldots z_{n-1})$, and the general solution of (5) is, in accordance with the theory of linear differential equations, a combination, with constant coefficients, of these n distinct solutions. Thus the general solution of (5) may be written in the form

$$z = C_1 z_1 + C_2 z_2 + \ldots + C_{n-1} z_{n-1} \tag{6}$$

The constants C are entirely arbitrary and we choose them so that the function z of t defined by (6) vanishes together with its derivatives up to the $n-3$rd inclusive when $t = \tau$; the $n-2$nd derivative, on the contrary, assuming the value $E(\tau)/A$. The prescribing of the values of z and its derivatives up to the $n-2$nd, inclusive, in this way for a particular value τ of t gives us exactly $n-1$ linear equations for the determination of the values of the constants C which occur in (6). These constants will depend on the particular value τ of t chosen to enable us to determine them by means of the conditions stated and they will, in addition, be proportional to $E(\tau)$ since the right hand members of the $n-1$ linear equations for the C's are all zero save one which is precisely $E(\tau)/A$. We shall indicate these facts by writing z of (6) in the form

1. Johns Hopkins University.
2. See Maxwell's Theory of the Layer Dielectric, F. D. Murnaghan, A. I. E. E. Journal, February 1927, p. 132.
3. The symbol D stands for $d/d\,t$ and is used throughout the paper symbolically as an algebraic quantity. For the use of the symbolic operator $D + b$ in the solution of linear differential equations with constant coefficients see any standard treatise on the subject, for example, Cohen's Differential Equations (Heath & Co), p. 96.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Feb. 13-17, 1928.

$$z = E(\tau)\, v(t, \tau) \tag{7}$$

The fact that the coefficients in the differential operator $F(D)$ of (5) are constants tells us further that the function v of the two arguments t and τ does not really involve them separately but is rather a function of their difference $(t - \tau)$. In fact the functions z_1, etc., are exponential functions of the time and these exponential functions reproduce themselves, multiplied by a constant factor, when differentiated with respect to the time. Hence each C occurs, in the $n - 1$ linear equations which serve to determine them, multiplied by the same factor $e^{\delta_r \tau}$, say, in each of the equations. This tells us that the $v(t, \tau)$ of (7) is of the type

$$v(t, \tau) = B_1\, e^{\delta_1 (t - \tau)} + \ldots + B_{n-1}\, e^{\delta_{n-1}(t - \tau)} \tag{8}$$

where the B's are pure numbers independent of both t and τ. The δ's are the zeros of the polynominal $F(D)$. We have found, then, a function

$$z = E(\tau)\, .\, v(t - \tau) \tag{9}$$

which satisfies the homogeneous equation (5) and which vanishes together with its derivatives with respect to t up to the $n - 3$rd inclusive when $t = \tau$ (*i. e.*, when the argument $t - \tau$ of the function v is zero); the $n - 2$nd derivative assuming the value $E(\tau)/A$ when the argument of v is zero. We now proceed to show that the function y of the single variable t, defined by the integral

$$y = \int_0^t E(\tau)\, .\, v(t - \tau)\, d\tau \tag{10}$$

is that particular solution of the equation (4) which vanishes together with its time derivatives up to the $n - 2$nd, inclusive, when $t = 0$; in fact, since the variable t occurs in two places— the integrand and the upper limit—in the expression for y we have for the time derivative of y

$$D\, y = \int_0^t E(\tau)\, .\, D\, v(t - \tau)\, d\tau + E(t)\, .\, v(0)$$

The second member on the right hand side vanishes, since the function v has been so arranged as to vanish when its argument is zero. Proceeding to the second time derivative we find in the same way that

$$D^2 y = \int_0^t E(\tau)\, .\, D^2 v(t - \tau)\, d\tau$$

and so on up to the $n - 1$st time derivative, which is slightly different; here the second term in the expression for the time derivative of the integral does not vanish, since the $n - 2$nd time derivative of v does not vanish when the argument of v is zero but has the value $1/A$ then. We have, therefore,

$$D^{n-1} y = \int_0^t E(\tau)\, .\, D^{n-1} v(t - \tau)\, d\tau + E(t)/A$$

Upon combining these results and remembering that the coefficient of the highest order derivative, D^{n-1}, in $F(D)$ is A, we have

$$F(D)\, y = \int_0^t E(\tau)\, .\, F(D)\, v(t - \tau)\, d\tau + E(t)$$

The first member of the expression on the right vanishes since the function v of t is a solution of the homogeneous equation (5), *i. e.*, $F(D)\, v(t - \tau) = 0$ for all values of the argument $(t - \tau)$. This shows that y, as defined by (10) is a solution of (4), and since all the derivatives up to the $n - 2$nd, inclusive, are expressed as integrals, the range of integration being from zero to t, all of these derivatives and the function y itself vanish when $t = 0$.

The various displacements f_r are now obtained from the auxiliary function y by operating on it in turn by the product of all the $(D + b)$'s but the single one $(D + b_r)$. From the expressions just given for the various time derivatives of y up to the $n - 1$st we have, for example,

$$f_1 = \int_0^t E(\tau)\, .\, (D + b_2)(\ldots)(D + b_n)\, v(t - \tau)\, d\tau + E(t)/A \tag{11}$$

showing that the common initial value of all the displacements is $E(0)/A$. It will be convenient to introduce the notation

$$h_1(t - \tau) = (D + b_2)(\ldots)(D + b_n)\, v(t - \tau) \tag{12}$$

etc., the function $h_r(t - \tau)$ being the result of operating on the function $v(t - \tau)$ by the product of all the $(D + b)$'s but $(D + b_r)$. We have, then, the various displacements given by the formulas

$$f_r = \int_0^t E(\tau)\, .\, h_r(t - \tau)\, d\tau + E(t)/A \tag{13}$$

The n functions h_r all have the same value $1/A$ when the argument $(t - \tau)$ is zero. The formulas (13) become more significant, from a physical point of view, if we change their appearance by an integration by parts. On introducing the functions $\varphi_r(t - \tau)$ by the equations of definition

$$\varphi_r(t - \tau) = \int_\tau^t h_r(t - s)\, ds + 1/A \tag{14}$$

so that

$$\frac{d}{d\tau}\, \varphi_r(t - \tau) = -\, h_r(t - \tau)$$

we have from (13)

$$f_r = E(0)\, \varphi_r(t) - E(t)\, \varphi_r(0) + \int_0^t \frac{dE}{d\tau}\, \varphi_r(t - \tau)\, d\tau + E(t)/A$$

The second term in the expression on the right hand cancels the fourth, since when the argument of φ_r is zero, the two limits of the integral of (14) coincide so that $\varphi_r(0) = 1/A$. Then we have the final definite result

$$f_r = E\,(0)\,\varphi_r\,(t) + \int_0^t \frac{d\,E}{d\,\tau}\,\varphi_r\,(t - \tau)\,d\,\tau \qquad (15)$$

This equation gives a physical interpretation to the functions φ; for, on writing $E\,(t) = 1$ in (**15**), we see that $\varphi_r\,(t)$ is the displacement in the rth layer when a constant unit e. m. f. is applied at time $t = 0$ to the dielectric supposed uncharged.

The result given in (**15**) is the mathematical expression of the Boltzmann-Hopkinson Principle of Superposition as applied to the displacements. It is evident from its mode that the principle of superposition is valid not only for Maxwell's theory of dielectric absorption but for any theory which leads to a system of differential equations which are linear and have constant coefficients. For example a theory in which the current density was connected with the displacement by a second order equation of the type $(D^2 + b_r\,D + c_r)\ f_r = u$ would have the principle of superposition as a consequence.

Once the displacements have been found the current density u follows at once from (**1**). Writing

$$\psi\,(t - \tau) = (D + b_r)\,\varphi_r\,(t - \tau) \qquad (16)$$

(it is easily verified that the expression on the right has the same value for all the layers) we find

$$u\,(t) = E\,(0)\,\psi\,(t) + \int_0^t \frac{d\,E}{d\,\tau}\,\psi\,(t - \tau)\,d\,\tau + \frac{d\,E}{d\,t}\Big/ A \qquad (17)$$

The physical meaning of the function $\psi\,(t)$ is evident from this formula; it is the current at time t due to a constant unit e. m. f. applied to the uncharged dielectric at time $t = 0$. The principal of superposition is not valid for the entire current but the first two terms of (**17**) may be found by means of that principal and then the complete current follows by adding the displacement current which is given by the third term.

We have given elsewhere[4] the expression for the function ψ in terms of the constants of the layer dielectric and the formula (**17**) furnishes a ready method for calculating the current due to any type of applied e. m. f.

4. A. I. E. E. JOURNAL, February 1927, p. 132.

Telephone Toll Plant in the Chicago Region

BY BURKE SMITH[1] and G. B. WEST[1]

Associate, A. I. E. E. Non-member

Synopsis.—*This paper described the telephone toll system in the region within a radius of about 50 mi. from Chicago. In this system have been established 21 toll centers at which are handled the toll traffic of their own exchanges and 95 other exchanges in the area. Descriptions are given of the toll plan and the toll plant, methods of handling toll calls, volume of traffic handled, etc. A most important consideration is the very rapid growth taking place in toll-service requirements in this region.*

COOK County and its seven adjacent counties in Illinois, and two in Indiana, together form the metropolitan area which is referred to in this paper as the "Chicago Region." Within this area there are about three and one-quarter million people in Chicago proper, with another one and one-quarter million distributed in about one hundred communities in proportionately decreasing densities from the Chicago city limits to the outer boundaries about fifty miles distant. The growth of the population in this area is at the rate of approximately a million per decade.

This area is served telephonically through local exchanges which are, for the most part, identical with the one hundred odd communities already referred to, and each receives service within its area under its local service tariffs. Between any one community and any other community, service is, in general, subject to an additional tariff or toll charge based on the center to center distance.

The general advancement of this region has been material. This has been more than reflected in the accompanying increase in telephone business. Within this business the rapidity of increase has been even more marked in the toll than in the local phase. Since all indications point to a continuance in this same relative progress, it may be appreciated that the toll development will present a continuing problem if no other factor than magnitude alone need be considered. Along with magnitude, however, there are problems of re-alinements of distribution as communities of interest and methods of operation change and plant design advances.

It is obviously as impractical to provide each local exchange with direct or fixed connections to every other exchange as it is to so deal with the various subscribers' stations within a local exchange. Switching or distribution centers must, therefore, be arranged which result in greater toll plant efficiencies and toll line route concentrations. The actual result of this in the Chicago region has been the establishment of 21 toll centers, at which are handled the toll traffic of their own exchanges and the other 95 exchanges in the area. These 95 exchanges have, therefore, become, for toll

1. Both of Illinois Bell Telephone Co., Chicago, Ill.

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purposes, satellites to these centers, or as it is generally expressed, "tributary exchanges." It is expected that these 21 centers may be still further reduced with improvements in methods and plant design.

Toll traffic between these toll centers, whether originating at the centers or at their tributaries, is handled by one of three operating methods known respectively as:

1. *The Toll Board Method,* in which the calling subscriber is connected with the recording operator, familiarly known as "Toll" or "Long Distance." At the present time the recorder takes the details of the call and dismisses the subscriber until a line operator can complete the call. This method is now undergoing a change. As soon as equipment rearrangements are available the work of the recording and line operators will be combined and marked service improvement effected.

2. *Two-Number Toll Board Method,* in which the "A" operator accepts the call and passes it to a "Toll Board" operator, who handles the call while the calling subscriber remains at his telephone. This method will tend to merge with the improved toll board method.

3. *A-B Toll Method,* in which the "A" or subscriber's operator, on receiving a call from the subscriber, supervises the call through to the called station, the calling subscriber staying at the telephone.

Under the last two methods only calls made for a station by number can be completed, and the first method is used for all calls on which a particular person is asked for. The determination of the proper use of each of these three methods involves consideration of service requirements and economies. In general, the so-called A-B method is used for short-haul traffic of large volume, the two-number toll board method for short and intermediate distances of lesser volume, and the toll board method for long-haul traffic of small volume. These, of course, are only general groupings, and the method adopted in any individual case is based on the actual conditions to be met.

There are, of course, also variations within these methods, such as, for example, the use of a tandem switching center in an A-B method. This variation as applied to Chicago, consists of a tandem board at which are centered toll trunks from Chicago exchanges as well as from outlying exchanges. Calls received by the "A" operator at a Chicago exchange, for one of these outlying exchanges, may be routed via the tandem switching operator, who in turn connects through to the called office, via the toll trunks available to her. In this way it is not necessary to have direct toll lines from every local board in the area to every other local board; yet, at the same time, it is possible to complete these calls by the A-B method. There is at present only one tandem board in the Chicago region, and this is located in the loop district. Of course, as the volume of traffic between any two exchanges, which is handled through the tandem board, increases sufficiently to make it economical, direct toll circuits between the two exchanges are provided.

Progress in the Chicago region has been steadily changing from a condition of practically all toll board operation with the hang-up method, to two-number and A-B toll methods without hang-up as the toll volumes have increased and station-to-station service has become more popular until today fully 87 per cent of the Chicago regional toll traffic is handled by the A-B method. The improved toll board method will further increase the percentage of business handled on a "no hang-up" basis.

In this connection, it should be noted that concurrently with this change from toll board to A-B operation has come a marked change in speed of service. The average speed of service, that is, the average time from the request for a number by the calling subscriber to the ringing of the bell of the called subscriber, under the toll board method, averaged about seven min., while the speed of service under the two-number and A-B methods averages less than one min. Part of this reduction in time of connection is, of course, a direct result of the methods of operation, although part of it is also a result of the more liberal provision of facilities. However, such provision to permit of faster service has resulted in stimulating the use of the toll service, with a corresponding increase in the size of circuit groups and in the efficiency and speed with which these circuit groups can handle the traffic.

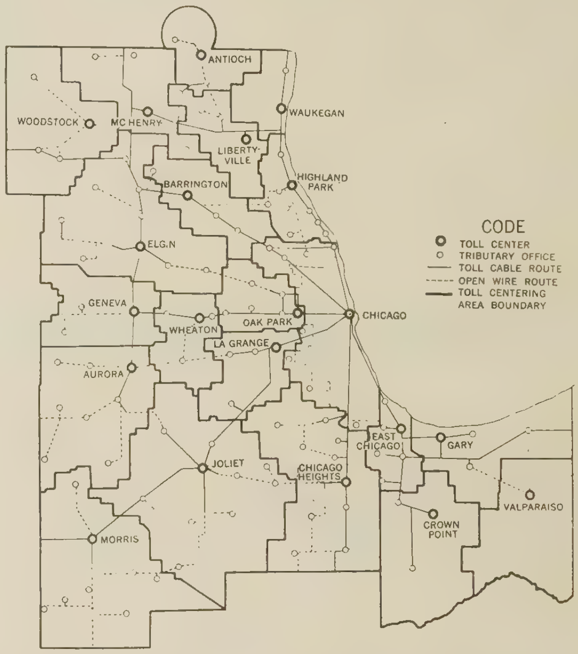

Fig. 1—Toll Fundamental Plan

Associated with this regional toll traffic, there is the traffic which goes out of the area to more distant points, and that which comes into the area from distant points including traffic to and from such points which must be switched at a center, like Chicago. The economical

provision of the plant to care for this extra regional traffic, with that for the short-haul traffic, further adds to the complexity of the plant design.

The provision of the plant for this intra and extra regional traffic to be economically carried out must be based on some general plan of future development within the area. Such a plan, generally known as the "toll fundamental plan," projects volumes of traffic, anticipates methods of handling, and arranges toll centering, tributary and route layouts for some ultimate period, normally about 20 years in advance. Such a plan must, of necessity, be reviewed and revised from time to time to keep pace with the developments and changes in toll service requirements, and is a guide to current toll plant construction rather than an absolute control of it.

Illustrations of some of the problems of growth and development of toll plant within the Chicago region follow:

Referring first to the toll fundamental plan, Fig. 1 shows the grouping of the exchanges in the Chicago region around the toll centers. For example, the small exchanges around Joliet under this plan reach Chicago and other points via Joliet. This figure incidentally indicates the several toll routes radiating from Chicago, such as the route along the North Shore, that northwest from Chicago toward Barrington, another directly west through Oak Park and Geneva, and the one southwest toward Aurora with a branch toward Joliet and Morris; still another directly south to Chicago Heights, and one southeast to East Chicago which forms part of the main route to points East, including New York.

Considering now the growth in toll traffic in this

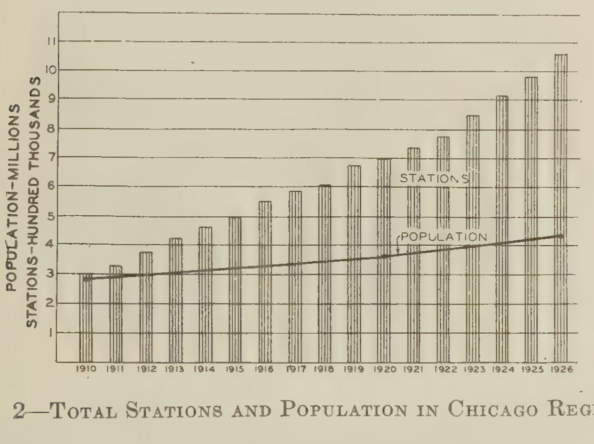

Fig. 2—Total Stations and Population in Chicago Region

region, there were ten years ago approximately 560,000 telephones with approximately 11,600,000 toll messages per year. In this same area, with something over one-million telephones, we are now handling approximately 46,000,000 toll messages per year, or an increase of 300 per cent, while the number of telephones has increased only 90 per cent, and the population approximately 33 per cent. These relations are shown diagramatically in Figs. 2 and 3.

While a large part of this increase in toll traffic is within a 50-mi. radius of Chicago, yet the longer haul has increased greatly, as for example, between Chicago and St. Louis, 185 messages per day ten years ago, compared with 650 messages today; between Chicago and Detroit, 180 messages per day ten years ago compared with 1000 messages today.

Toll cable has been the solution of the increasing toll circuit requirements, since there is a definite limit

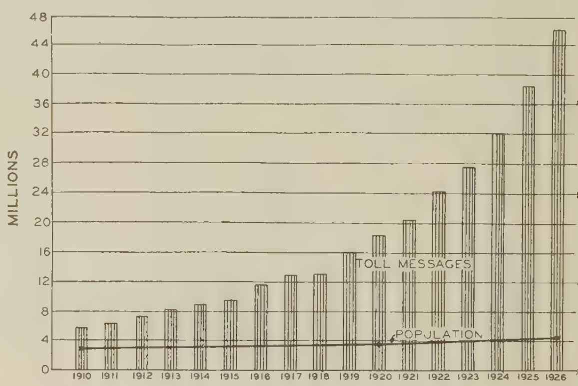

Fig. 3—Total Toll Messages and Population in Chicago Region

to the number of circuits which can be provided by open wire.

Notwithstanding the continued use of open wire on the less dense routes, the extension of cable has decreased the toll open wire in the plant. This is shown in Fig. 5. It will be noted that cable wire mileage has increased from 36,000 in 1916 to 224,000 in 1926, an increase of 520 per cent in 10 years, while toll aerial wire mileage in this region has decreased somewhat during this period.

The rapid extension of the toll cable plant is shown in Fig. 4 on which is indicated the cable in service five years ago, the cable now in service, and that rather definitely foreseen within the next five years. It should be noted that in several of the routes shown a second cable, and in some cases a third and fourth cable, has been placed.

In designing such a cable network as this, there are a great many problems which must be solved before the plant can actually be provided; *e. g.*, starting out with an assumed grade of transmission, which it is necessary to provide from any station to any other station, the distribution of the losses must be economically apportioned. Take the simplest case of toll connection, consisting of a calling subscriber's loop, the called subscriber's loop, and the connecting toll circuit. Probably it would be possible to apportion 45 per cent of the loss to each subscriber's loop, and design the transmission of the toll circuit so that only the remaining 10 per cent would be in that portion of the connection. Or it would also probably be possible to assign 10 per cent of the loss to each subscriber's loop, and take up the remaining 80 per cent in the toll circuit. There is, of course, an economical division of these losses, and these must be determined in designing the toll plant.

Consider the design of the tandem trunk plant. These trunks may be classified into two groups, those connecting the tandem board with city offices, and those connecting the tandem board with suburban offices. If we should divide the total allowable line loss between these two groups equally, we would not obtain an economical balance, since the tandem trunk which is extended into suburban territory may be as much as fifty mi. in length, while the city tandem trunk will be very much shorter. There is, therefore, a very material

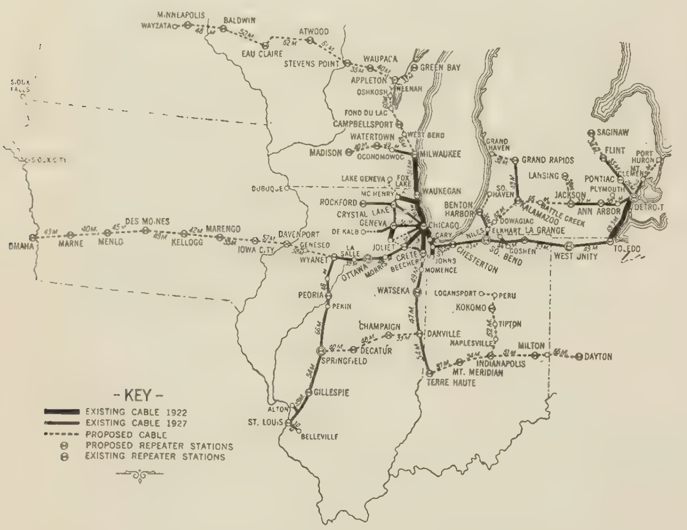

Fig. 4—Toll Cables in the Great Lakes District

saving by dividing the allowable losses unequally between these two classes of tandem trunks. In Chicago a study of the costs involved showed that this division of losses should be made up as follows:

Tandem trunks in the metropolitan zone (within the city limits principally) .... 5.0 Transmission units[2] allowable loss.

Tandem trunks within the suburban zone............10.4 Transmission units allowable loss.

In the earlier days of the telephone business, all toll circuits of any appreciable length were provided by bare wire strung on insulators, and it was not until a relatively few years ago that the development of the art permitted the use of cable circuits for this purpose. The earlier toll cables consisted simply of insulated wires, twisted in pairs. In this period transmission losses were so large that this type of cable could only be used for short distances, even though consisting of 13 and 10 gage wire.

The development of the loading coil, which has been described in other papers presented before the Institute, permitted further use of cable, and made cable available for increased length of haul where the volumes of traffic demanded additional facilities.

2. For description see paper by W. H. Martin, A. I. E. E. Trans., Vol. 43, 1924, p. 797.

Since their introduction, the development of loading coils has advanced materially. The first coils introduced into the toll plant, some 25 years ago, were of iron core construction. While these coils were satisfactory under the conditions for which they were developed, when telephone repeaters became available it became desirable to provide improved types of loading coils. A loading coil having a pressed powdered iron core was, therefore, made available. The outstanding advantages of this coil was its higher magnetic stability and the smoother impedance conditions on the lines resulting from its use.

This coil has proven satisfactory for repeatered circuits. It is now being superceded for new construction, however, by a new type of coil having a pressed powdered permalloy core. This new core material permits a large reduction in the size of the coils without degrading established efficiency standards, and will result in large plant economies. Fig. 6 shows the relation of size of pots required to incase a given number of the new and old coils. This reduction in size is of great advantage where such coils must be placed in underground systems in congested city streets, or where in the country it is desirable to place them on pole fixtures.

Another development in the cable art is that of quadded cable. In this type of cable two pairs of wires, each constituting a circuit, are twisted together to form what is known as a "quad," and these quads

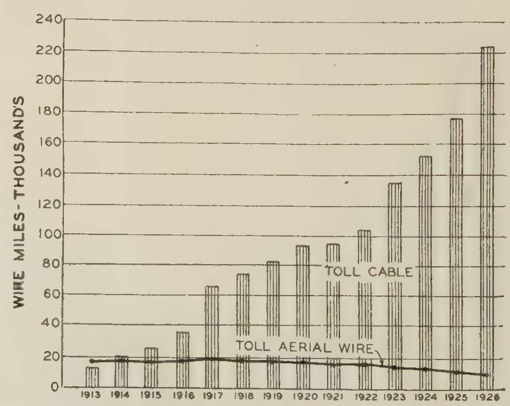

Fig. 5—Toll Cable Wire and Aerial Wire Mileage in the Chicago Region

may be used to provide a phantom circuit, thereby increasing the message capacity of the cable by 50 per cent. While this plan of making available a phantom circuit had previously been used in the open wire plant, t was not until quadded cable was developed, that the phantom was available in cable circuits. The use of quadded cable for circuits using direct signaling, however, introduced another complication, in that the phantom circuit requires the introduction of a repeating coil at each end of each of the physical circuits, which will, of course, not permit direct-current

signalling. It therefore becomes necessary in these cases to "by-pass" direct-current signaling around the windings of the phantom repeating coil, in order to make use of the phantom possibility. The economics of this form of signaling must be studied in each individual case.

Another important factor in the extension of cable for toll purposes is its immunity from storm damage. As is well known, open wire is subject to very serious breaks in the sleet storm area, while cable is practically immune from damage in such storms. It is estimated that to make an open wire line strong enough to give a strength of construction comparable to that obtained with aerial cable would require very large poles on very-short spacing or other special construction. Such a line also would need at least No. 8 B.W.G. hard-drawn copper wires. It is not certain that even such a line would stand up under severe storm conditions. Aerial cable construction on the other hand has been in use long enough to indicate that construction will almost never go down during the severest storms. In the extreme cases in which a break does occur the circuits in the cable probably will continue to give service. An example of how modern toll cable construction enables service to be given even if the poles are broken and the cable is thrown to the ground was shown in the case of a cable pole line between Maywood and Elmhurst, suburbs of Chicago. This line which was

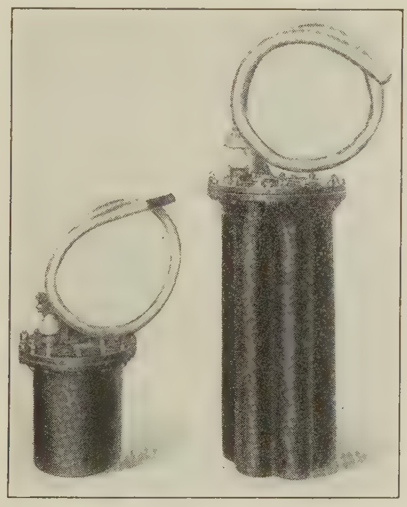

Fig. 6—Comparative Size of Loading Coil Cases

Each case containing 200 loading coils:
Left—Permalloy Core Coils—Weight 725 pounds
Right—Iron Core Coils —Weight 1750 pounds

blown down in May 1927, during a wind storm of great severity carried two toll cables and also a subscribers cable. Although over a mile of pole line was blown down, the only trouble which occurred was due to a crack in the sheath at a splice which resulted in nine pairs being temporarily out of service out of a total of 845 pairs in the two toll cables.

Cable plant must of necessity be added in rather large units with fairly large margins over immediate requirements. If futu e requirements are overestimated, this will result in an appreciable amount of idle plant investment, or if underestimated, uneconomical reenforcement or replacement becomes necessary. The provision of cable thus requires careful forecasts for long periods as to the probable traffic volumes and circuit requirements.

Even with the developments in cable and loading coils, which are discussed previously the distance to which cable could be extended for toll purposes was

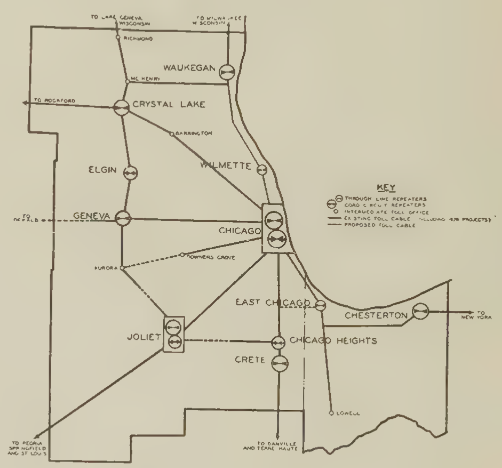

Fig. 7—Location of Telephone Repeater Stations and Their Relation to the Toll Cable Network in the Chicago Suburban Area

limited, and it was necessary to use No. 13, and in some cases No. 10, gage conductors to meet transmission requirements. With the development of vacuum tube repeaters[3] and their availability for use with toll cable, the distances to which such cable could be economically extended was increased very greatly. Furthermore, as a result of the use of repeaters, it has been possible to reduce the gage of cable circuits, so that modern toll cables now seldom contain conductors larger than No. 16 gage, and the greater proportion of conductors in such cables is generally No. 19 gage.

The first installation of vacuum tube type repeaters in the Chicago region was in 1914 in connection with the transcontinental line. This was a small installation, and growth in repeaters in this territory continued at a fairly slow rate up to about 1924. This slow growth was due to the fact that it had been necessary to install practically no long toll cables other than that extending between Chicago and Milwaukee. Beginning with the year 1924, toll cable was rapidly extended in various directions from Chicago for distances of over 100

3. See paper on *Telephone Repeaters*, by B. Gherardi and F. B. Jewett, Trans. A. I. E. E., Vol. 38, 1919, p. 1287. Also by A. B. Clark on *Telephone Transmission on Long Cable Circuits*, Trans. A. I. E. E., Vol. 42, 1923, p. 86.

mi. The Chicago-New York cable, for example, was completed in 1925, and the Chicago-St. Louis cable, which lies almost entirely within the State of Illinois, was completed in 1926.

At the present time, there are approximately 750 repeaters in use in the territory of the Illinois Bell Company, a very large proportion of which is in the Chicago region. Fig. 7 shows the location of repeaters in this Chicago region.

Another problem which has come up in recent years, although not expected to be a recurring problem, is concerned with the quality of transmission. When toll circuits consist of only non-loaded open wire, the effect of the line on intelligibility is negligible, as circuits of this type are very nearly distortionless. The introduction of loading into the telephone plant, however, has brought with it a certain amount of restriction of the range of frequencies transmitted, varying in degree with different types of circuits. It is well known that loading has the property of cutting off or suppressing frequencies above a certain number of cycles, depending on the character of the loading.[4] One of the fundamental questions of loading has been to determine what range of frequencies should be transmitted to furnish a satisfactory grade of speech without undue distortion. Early studies indicated that a cutoff frequency of about 2300 cycles would be satisfactory. These studies were ba ed on measurements made by ear methods, however, and have been supplanted by more recent studies made by more scientific means. These studies show that it is economically practicable and desirable to set a limit of 2800 cycles as the minimum cutoff frequency in loaded cables, and accordingly all new toll plant is now designed on a basis of a cutoff frequency of 2800 cycles or better.

In Chicago, at the time the decision was made to adopt a higher cut-off frequency, there were installed about 50,000 loading coils in the local trunk plant. Many of these were on trunks which are used on toll connections, such as direct A-B and tandem trunks and toll switching trunks. These trunks had a cutoff frequency of 2300 cycles. A study of the Chicago city trunk plant showed that it was economically desirable to change the spacing of coils so as to raise the cut-off to 2800 cycles or better, and this work has now been practically completed so that all toll calls, with the exception of those involving a few circuits in some of the first toll cables installed, are now routed over trunks having the high cut-off features. As a net result of this increase in the cutoff frequency, a lower volume equivalent can be used, which means that a given type of loaded circuit can be used for a somewhat longer haul than if the cut-off were lower.

With the increasing complexity of the toll plant in recent years, it has appeared desirable to make periodical surveys of transmission conditions in a toll operating area to determine whether the existing plant is being used to best advantage from a transmission standpoint and to serve as a guide to the economical development of the toll plant during a period of say five years in the future. In considering the need for such a survey it should be noted that in the design of the toll plant, provision must be made for handling traffic which is switched to points beyond two given toll centers, as well as that which terminates at the two centers. This traffic for a given circuit group between two toll centers may amount to only a small percentage of the terminating traffic and means must be provided for taking care of transmission on such business which will not react seriously on the cost of providing facilities suitable for terminating business. Adequate transmission on switched calls may often be provided economically by the installation of repeaters[3] or by setting aside a certain proportion of circuits in a given circuit group for use in switched business and designing those circuits so they will be of a high enough grade to be used for either switched or terminating business. The economical location of repeater points and determination of the proper balance between circuits designed for terminating business and those designed for switched business can best be decided by a comprehensive study of transmission conditions for the entire area.

In making a transmission survey, an analysis of toll traffic is prepared covering the whole area for a representative month, showing both terminating and switched traffic and indicating the present transmission conditions as compared to the transmission objectives which have been established. By dividing the territory into natural subdivisions such that the traffic for different parts of the territory passes through a relatively small number of main switching points, it is often found that the analysis at a particular switching point will show that transmission improvement of a relatively small number of circuit groups will provide satisfactory transmission on all business switched through that particular point. It is also possible to pick out the particular centers where toll transmission under present conditions does not meet assumed objectives. A transmission study of this kind supplements the toll fundamental plan and is of assistance in the proper routing of toll traffic so as to fit in with expected future toll projects.

There are, of course, many other problems in the design of the toll plant relating not only to what might be termed transmission design but also methods of construction and problems of economics entering into the design of the plant. However, the greatest problem, as indicated in the earlier part of the paper, probably is that brought about by the extremely rapid growth taking place in the toll service requirements of the Chicago region.

4. See paper on *Development and Application of Loading for Telephone Circuits*, by Thomas Shaw and William Fondiller, Trans. A. I. E. E., Vol. 45, 1926, p. 268.

Discussion at Pacific Coast Convention

ADVANCE PLANNING OF THE TELEPHONE TOLL PLANT IN LONG-DISTANCE COMMUNICATION[1]

(CHAMBERLIN)

TANDEM SYSTEM OF HANDLING TOLL CALLS IN AND ABOUT LOS ANGELES[2]

(JACOBSON AND WHEELOCK)

DEL MONTE, CAL., SEPTEMBER 14, 1927

M. R. Sullivan: Speaking as a telephone traffic engineer, I should like to endorse what Mr. Chamberlin has said with respect to the traffic features involved in advance planning of telephone toll plants.

Traffic in the telephone industry takes the form of telephone calls or messages and since the plant is provided for the purpose of transmitting messages, the traffic features—the volume of traffic, the character of the traffic, the routing of the traffic, and the manner of handling of the traffic—are of controlling importance in the determination of the size and type and arrangement of the plant to be provided.

Mr. Chamberlin has outlined the important function of the commercial surveys in forecasting telephone developments with respect to growth in the number of telephones and their distribution by area, and by classes of telephone service.

Of equal importance are the forecasts of telephone calls per telephone. Telephone usage per telephone—particularly toll usage—does not remain constant year by year, but varies with business activities, and is subject to other influences, so that in the advance planning of the telephone toll plant it is necessary to give very careful study to the trend in the usage per telephone.

During the past few years, and especially during the last one or two years, there has been a marked trend upward in the toll usage per telephone. Many influences, no doubt, have played a part in this greater usage of the service. A feature of outstanding importance in this increase in toll usage lies, undoubtedly, in the results secured through various improvements which have been made in the toll service. For example, transmission within the last few years has been materially improved. It is easier to carry on intelligible conversation over the circuits, and that, of course, has had an effect upon the amount of toll business offered. In addition, the speed of handling the calls, and the convenience with which the call can be placed, has materially improved.

Up to a year or so ago, for a long-distance call, the calling party had to give detail of the call to the long-distance operator, hang up the receiver, and later be called back when the connection was ready, or when a report on the call was obtained. This manner of handling a toll call required five or six minutes.

Today by giving the number desired to the long-distance operator, the chances are about nine to ten that the call will be completed immediately and without the necessity of even hanging up the receiver. The convenience of placing calls and the improved speed which this change has brought about has an effect in stimulating the number of toll calls offered.

Another recent change of considerable importance in the handling of toll calls is the proportion of calls handled by the "exchange operator." When I say exchange operator I refer to those completing connections from one telephone to another in the same exchange. The easiest way of placing a toll call is for the party calling simply to give the number of the desired call to the exchange operator, in the same manner as for a local connection. This method also produces the fastest service. For many years, large numbers of the toll calls have been handled by this method but of recent years there have been developments which greatly extended the range to which this most desirable of operating methods can be applied.

1. A. I. E. E. JOURNAL, October, 1927, p. 994.
2. A. I. E. E. JOURNAL, December, 1927, p. 1415.

One of the developments is the improved tandem system of routing toll calls, which Mr. Wheelock has described. The result is that today a very much larger proportion of the toll calls is handled by this method. Take the exchange of Monterey; something like 48 per cent of all the toll calls originating at this exchange are handled by the exchange operator; whereas two or three years ago none of the toll calls was so handled. This improved method, therefore, has had application not only at the large metropolitan exchanges but also at the small exchanges.

I think it might be said that, like the automobile industry, the telephone toll business is constantly producing a bigger and better service; and in the advance planning of the toll plant, it is necessary to foresee the further improvements which will be made in the toll service and the effect these improvements will have on the volume of toll business offered and the size of the plant required.

R. C. Barton: Mr. Chamberlin's paper makes clear certain high lights of technic of the telephone business, and why universal and uniform telephone service is a natural objective.

As he has pointed out the value of the service to those who have it is increased by each addition to the system. Universal service, therefore, becomes a strong objective. He has indicated that the service must satisfy the party called as well as the calling party, so that service from the customer's viewpoint is demanded, and that calls for uniformity and standardization.

The paper brings out three important and distinctive characteristics of the telephone plant. One is that there is a very great multiplicity of lines and associated apparatus; another, that each line must be electrically smooth and stable in its operation; and the third, that the character of the telephone plant is continuously and rapidly changing.

In regard to this great multiplicity of lines exclusive use of the lines between parties is, to some extent, obviated in the toll-plant through the use of phantom circuits and carrier channels; however, Mr. Chamberlin's description of the San Francisco-Sacramento toll cable shows that multiplicity of lines is a strong characteristic of the telephone plant. This is more pronounced in the exchanges where the lines provided in one office district may be of the order of 100,000 and the conductor footage of the order of hundreds of millions.

Stability and smoothness are required in the electrical characteristics of the lines because of the complicated wave pattern which must be faithfully transmitted. The effect of rapid change may be appreciated by considering the condition produced when it becomes necessary to throw all the wires on a 50- or 60-wire toll line into cable.

These distinctive characteristics of the plant and of the service are largely responsible for the special engineering, construction and maintenance practises which are followed in the telephone art. One of the practises which receives very special emphasis has been made the key-note of Mr. Chamberlin's paper. It touches those activities which have to do with the study of the field of operations with respect to potential telephone development and the preparation of well matured plans, looking far to the future, to serve as a guide in the orderly placing of the plant.

Now the nature of the problem also requires another kind of advance preparation which takes the form of engineering, construction and maintenance handbooks. These are prepared to relieve the engineers of much of the work they would have if each job were designed from the ground up at the time it was being planned. These handbooks also insure the orderly placing of the plant in accordance with practises which have received nation-wide study and application.

It may be of interest to indicate something of the extremes to which it is desirable to go in such activities.

As one illustration, The Pacific System maintains a supply catalog which is available to all interested employees, and this catalog lists all materials, tools, and apparatus used in the conduct of their work. It is profusely illustrated and comprises about 500 letter-size pages. Among the items listed in this catalog are the handbooks previously mentioned. There are 75 of these devoted to the subject of construction methods alone, and some 100 supplementary leaflets affecting these. The construction methods handbooks cover such subjects as pole-line placing, underground conduit construction, guying, aerial-cable placing, etc. To the subject of aerial-cable placing alone, 120 handbook pages are devoted. These are well illustrated, and this book is typical of the others. Illustrative of the engineering handbooks is one on pole-line design. With this book, the engineer may quickly and easily determine the class of pole to select for any set of conditions, such as service value of the line, wire and cable load, temperature, wind and sleet conditions, span length, etc. Illustrative of the maintenance handbooks is one devoted to pole-line replacement and reinforcement inspection. This handbook prescribes the methods to be used in making inspections and includes tables of minimum ground-line circumference below which poles under the various conditions of load, service value, etc., are not permitted to go.

I should like to endorse Mr. Chamberlin's remarks regarding the value of cost-comparison studies in engineering, and the value to the student engineer of a fundamental knowledge of the procedure in such studies.

Making cost comparisons is a measurement process in which the principal unit is the dollar. One of the great physicists—Lord Kelvin, I believe—has written: "When you can measure what you are talking about, you know something about it; and when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."

The rules of the mathematics employed when relating the various quantities developed in a measuring process require all quantities to be expressed in like units. For example, in a space measurement, units of length may arise as inches, feet, and yards, and require all to be expressed as feet by the application of suitable conversion factors. Likewise, in measurements where the dollar is the unit, it is required that before quantities of money may be properly compared, they must be operated upon by suitable conversion factors which will reduce all expenditures and investments such as first costs, present values, periodic payments, future recoveries, and the like, to a common time basis. The laws governing the set-up of the postulates and the facts in this sort of problem, and the method of solution, constitute the fundamentals of cost analysis, and it is these fundamentals which I agree with Mr. Chamberlin should be given some prominence during the college course. This is not done now.

Bancroft Gherardi: I was particularly interested in the remarks about inductive coordination, for, in the last five or six years, I have been the representative of the Bell system, working with R. F. Peck, the representative of the National Electric Light Association on the Joint Engineering Subcommittee, to solve our problems of inductive coordination; and before we had gone very far into that work, we came to the conclusion that 10 per cent of our problem was technical and 90 per cent was to bring about between the people on both sides of the question, a friendly and cooperative approach to that question.

It is evident that here, as in other parts of the United States, the problem is generally being approached cooperatively, and thus we are able to find mutually satisfactory solutions.

N. B. Hinson: Mr. Gherardi has called attention to the fact that there are certain classes of work that can hardly be classed as electrical engineering being done by the telephone companies. Mr. Chamberlin in his paper has emphasized this fact, and the same thing is true of the power system where there are certain elements of planning which are not electrical at all.

The telephone companies were the pioneers in the making of development surveys and population studies which could be used in advanced planning. A number of the power companies are falling in line with the same idea and finding population surveys in rapidly growing territory, like southern California, very useful, especially where yearly increases as high as 15 and 20 per cent occur.

J. E. Heller (communicated after adjournment): Mr. Chamberlin has pointed out that the advance planning of telephone toll plant requires the coordinated effort of several departments, who, in turn, require specialists to solve the problems requiring their participation in the project.

As indicated in the paper, open-wire carrier-current systems and cable conductors may be used to provide long-distance communication circuits. The use of a given type of facility requires the determination of electrical as well as economic factors. After making allowance for the transmision losses of the trunking and local loop plant used at each terminal, it is electrically possible at the present time to talk with various facilities over the distances given below:

Type of Facility	Mi.
104 Open-wire	5000
165 Open-wire	6700
19-Gage 2-wire cable circuits	700
16-Gage 2-wire cable circuits	1200
19-Gage 4-wire cable circuits	1500

Since a given circuit may be used as a link in a long built-up connection, consideration must be given to the number of links involved and each link designed so that it may be connected to any other link in the system. This requires that individual links must be somewhat shorter than indicated previously. The overall length for a given grade of transmission will also be affected by the amount of transmission loss allowed in the terminating trunks and loops. Undoubtedly future developments will materially extend the length over which it is practicable to talk with the present types of conductors.

Usually several plans are considered when a large addition to a plant, such as a toll cable, is indicated. Preliminary studies require an approximate electrical design of the circuits for each plan together with the cost of providing the facilities for a long period of years. The preliminary studies together with other basic data as presented by Mr. Chamberlin determine the plan to be adopted. After a particular plan has been adopted it is necessary to review the electrical design in order to determine the loading arrangement of the conductors, the location of sepeater stations, and the equipments to be placed at each station from year to year.

Carrier-current systems are being used extensively in the provision of additional facilities. The increase in facilities possible on a given lead by this means has been indicated in the paper. Before a number of systems can be operated on a lead it is necessary to rearrange the wires by transposition to reduce the interference between systems. The present standard arrangement makes use of alternate crossarms. While, in general, the costs are such as to make the use of adjacent crossarms for multi-channel carrier-telephone operation undesirable, in special cases, the added expense may be justified by other considerations.

The single-channel system developed for use on short hauls may be placed on the flat phantom groups of adjacent crossarms since the interference between systems of this type is less than that between multi-channel systems which occupy a higher frequency range.

COUPLING CAPACITORS FOR CARRIER-CURRENT COMMUNICATION OVER POWER LINES[1]

(Belt)

Del Monte, Cal., September 14, 1927

E. R. Stauffacher: Fig. 5 shows the installation of the tank-type of coupling capacitors at the Laguna-Bell Substation of the Southern California Edison Company. There is a similar installation at Big Creek No. 3 which totals four units of capacitors for the system. In both of the stations the units are connected to one of the two 220-kv. busses. This equipment has been in service for about a year and has been thoroughly satisfactory in its performance. There was some apprehension at first as to whether or not it was advisable to connect a new and untried piece of equipment to the 220-kv. bus but our experience shows that it is as reliable as any other apparatus designed for the same operating voltage. You can see that it gives a much more finished and workmanlike job than is possible with overhead wire coupling. It is of interest to note the statement regarding the effectiveness of coupling where the coupling wires are credited with a 7 per cent effectiveness of coupling while the effectiveness of the coupling capacitors is rated somewhere between 80 and 100 per cent.

The cable coupling capacitor has not been used on our 220-kv. line and we have no experience to relate concerning it. However, for voltages lying between 66 kv. and 154 kv., it should prove to be a means of making an effective and compact coupling.

Wm. Dubilier (by letter): I should like to point out certain facts concerning condensers for high-voltage operations:

There is no question as to the superiority of mica as a dielectric in a condenser over any other dielectric at present available. It must be remembered that mica is the only dielectric known which does not deteriorate with time, under electrostatic pressures.

Mica condensers are so constructed that the potentials are subdivided in such a way that individual units carry 1000 volts or less; therefore, the high-voltage problems, such as ionization in the condenser unit, corona effects and other difficulties that may be developed due to impurities of artificial dielectric material, as used in cables and porcelain, are not present with mica.

For the purpose of carrier-wave coupling, the mica condenser has been standardized in units of 22,000 volts. For higher voltages a number of those units are connected in series, eliminating the use of extremely high-voltage insulators necessary with all other types.

Moreover, this unit construction permits keeping only one or two units as spares, requiring considerably less investment, as compared to the types where the condenser unit is designed for line voltage.

Conditions in Europe, especially in territories surrounding Switzerland, are much more severe than are generally experienced in this country, and the electric railroads and power supply companies (such, for instance, as the Chemins du fer Du Midi) have been experimenting for many years with every known insulating material, and have finally adopted mica condensers as the most suitable in practically all of their installations operating at 60,000 volts. These capacitors have now been operating with great satisfaction for several years.

A carrier-wave coupling condenser developed in this country is shown in the accompanying Fig. 1. The four separate units are clearly seen mounted on top of each other. Such an installation would be suitable for 88,000 volts; for higher voltages units might be added, one for each 22,000 volts.

Fig. 2, herewith, shows an actual installation at the Sunnyside Substation, Ohio Power Company, Canton, Ohio, one of the properties of the American Gas & Electric Company, installed on their 132,000-volt circuit between Canton, Ohio, and Philo, Ohio, March, 1925. This installation consists of two columns, six 22,000-volt units in series per phase.

A number of installations of this nature are at present scattered over the country, and so far the results have fully justified the theoretical considerations which have led to the choice of mica condensers in preference to other types. Some of the installations have been in continuous use for about three years, and as the carrier-wave connecting system is the link which must be as nearly trouble-proof as possible, it is interesting to note that the majority of the installations have had no trouble whatever, while in other cases the trouble has been due to lightning strokes.

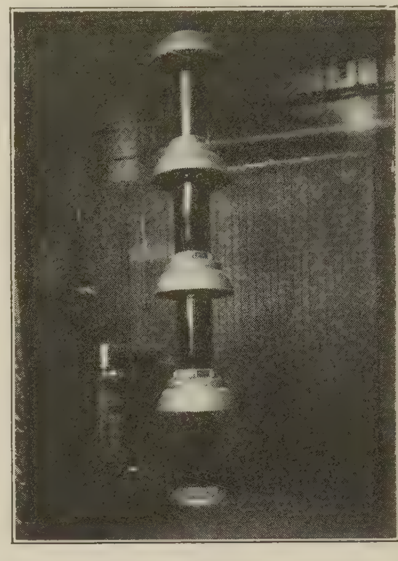

Fig. 1—Mica-type Coupling Condenser

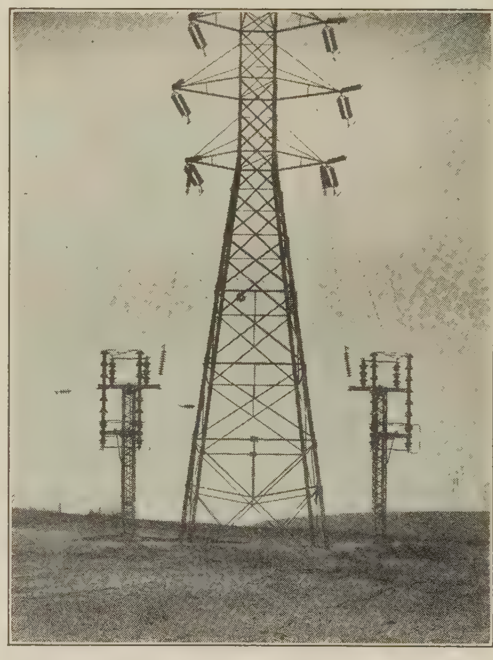

Fig. 2—Coupling Condensers on 132-Kv. Line

Sunnyside Substation, Ohio Power Co., Canton, Ohio, one of the properties of the American Gas and Electric Co; installed on their 132,000-volt circuit between Canton, Ohio and Philo, Ohio, March 1925. This installation consists of two columns, six 22,000-volt units in series per phase.

Philip Sporn (by letter): Mr. Belt has touched upon the question of the increased use of coupling capacitors as against coupling wires and has stressed, as a reason for that, the fact that

1. A. I. E. E. Journal, October 1927, p. 1051.

capacitors have greater effectiveness. I should like to point out however, that while effectiveness has undoubtedly a considerable amount to do with their increasing use, there is another factor which he has failed to point out. This factor has to do with lightning and while lightning is perhaps a subject that does not give much serious trouble in California, in the east and in the mid-west it is a subject that gives us many a sleepless night.

The work of Peek and others has shown that the ground wire is decidedly useful and very often an almost necessary part of a transmission line where lightning is much of a factor. The klydonograph work carried on by the various companies in the last two years has strengthened that viewpoint. However, whereas a ground wire is important on the line itself, it becomes doubly so at the two terminals of the line where apparatus has to be taken care of. Now what has been the practise with regard to coupling wires? In places where the line has been designed for one or two ground wires, the invariable practise has been to take the last four or five spans of the ground wire, insulate it, and use it as coupling conductor. From the standpoint of the coupling wire, this seemed the logical thing to do, but from the standpoint of the line as a whole, it was decidedly the wrong thing. The result, of course, was to give a line with a rising surge impedance at the two ends and the consequent increment in the steepness of any wave front as it approached the station. This is the reverse of the ideal aimed for, namely the decreasing impedance at the two ends. Viewed in this light, the decision between the coupling wires and coupling condensers is not very difficult. We have something like 22 carrier installations on our 132-kv. system and this involves coupling to approximately 34 different lines practically all of which are made through coupling capacitors. In the vast majority of cases the decision to go to coupling capacitors was influenced to a considerable degree by the considerations outlined above.

From the data on impulse strength of the various types outlined by Mr. Belt, it would appear that the tank type would be the most ideal capacitor. Unfortunately, however, it has the drawback that it is also the most expensive one. Looking for the next best, we find that for a given rating, the mica and oil-filled cable types have about the same impulse strength but the impulse ratios are decidedly different. It would appear therefore that the mica, if it could have 60-cycle flashover value cut down without affecting its impulse flashover, might very well compete with the cable type. In this respect, however, the general characteristics of the mica are not sufficiently well known and it would seem decidedly worth while to have more work done on the subject, particularly as in the present stage mica, from a standpoint of cost, would be decidedly the choice over cable. As regards the porcelain-type condenser (a type not discussed by Mr. Belt), this condenser utilizes materials that have been longest known and tried in the electrical circuit but in the present stage of development it certainly does not look as if it is ready to go on a system where high standards of safety are demanded. More work ought to be done on it.

T. A. E. Belt: Very complete tests at 60 cycles and impulse were made in order to check experimentally the electrical strength of both the cable-type and tank-type capacitors. Therefore, Mr. Stauffacher took little chance in connecting the tank-type capacitors directly to the bus at Laguna Bell and Big Creek No. 3.

Mica is a good dielectric for certain applications, but it has an objectionable characteristic which Mr. Dubilier did not bring out in his discussion; namely, the property of breaking down on steep wave fronts, such as lightning, at a lower value of potential than its maximum 60-cycle breakdown. This characteristic makes it necessary to over-insulate a coupling condenser, using mica for 60 cycles in order to have it stand up in service on a transmission line which is subjected to lightning impulse voltages. There is no measurable deterioration of an oil dielectric such as used in the cable-type and tank-type capacitors.

In general, American practise has not followed European practise, owing to the fact that operating requirements in this country are different from those in Europe and greater reliability is required.

I wish to acknowledge the help given by L. V. Bewley of the High-Voltage Bushing Department of the General Electric Company in the preparation of this paper. I also wish to state that the development of the cable-type coupling capacitor was carried out in cooperation with that department.

A CARRIER-CURRENT PILOT SYSTEM OF TRANSMISSION LINE PROTECTION[1]

(Fitzgerald)

Del Monte, Cal., September 14, 1927

E. R. Stauffacher: This novel and effective system of transmission-line protection offers great promise for lines operating at high voltage with a long-distance between stations.

It was my privilege last March to witness some of the tests of this equipment on the Ohio Power Company's system in the section of the system located near Zanesville and between the substations known as Newmark and Crooksville. This carrier-current pilot system of protection was applied to a 66-kv. line between the above stations and the stations were separated a distance of 35 mi. The tests were made on a rainy Sunday, and fourteen tests in all were made by means of putting short circuits within the section protected, and exterior to the section protected. The short circuits were phase-to-phase and phase-to-ground. There was, with possibly one exception, successful operation in all cases. When the short circuits were applied exterior to the section protected, the carrier-current system of protection kept this section in service; when the short circuit was within the section protected it eliminated this section and the short circuit promptly from the system.

One of the tests was particularly outstanding,—Test No. 6. This was a phase-to-phase short circuit between phases 1 and 2, was exterior to the section protected, and was rather severe, the current from one side of the system being 285 amperes, at 66 kv., and from another side 1785 amperes at 66 kv. The total amounts to a short circuit of about 230,000 kv-a.

While that is not so great as may be encountered on this system, still it is a sizable short circuit and for that particular system was enough to result in a very heavy jolt. It was quite interesting to notice the swaying or oscillation of the system for several seconds after the short circuit occurred. I believe that about 10 swayings were observed, swinging back and forth on the ammeter, where thousands of kilowatts were being exchanged across the section protected by this carrier-current protective system—and this section remained intact and stayed in service.

That would have been a very severe test for any directional-relay form of protection, and I doubt if the lines would have stayed in, for the current was sufficiently great to indicate that the short circuit was in that particular section, and the direction of current flow was from one side to the other.

The carrier current was apparently fast enough to keep up with the swayings back and forth, and the section did not trip out.

In conclusion, as I stated before, it appears to me that this system offers great promise. From the observation of the tests it looks as if there was something to be desired in regard to speed. The author informs me that the speed of operation can be increased appreciably by the preheating of the filament and continuous excitation of the plate.

In this particular test 50 per cent preheating of the filament was used, but the time can be cut down, by means of 100 per cent heating of the filament. Here is a case where it is necessary to balance the life of the tubes against the necessity for extra speed in eliminating trouble from the system. We are finding out that the elimination of a fault from the system with-

1. A. I. E. E. Journal, October, 1927, p. 1015.

out making the system unstable, is largely dependent upon speed and my only suggestion to the manufacturers is that they do all they can to speed up operation of this very unique system of differential protection.

Roy Wilkins (by letter): In protection against line faults there are two major conditions:

1st: Where the short-circuit current, either between the phases or from phase to ground, is several times the normal load current, such as is found in distribution systems in metropolitan areas.

2nd: Where the short-circuit currents are comparable to, or less than, the normal current in the line. Such conditions apply to high-voltage transmission lines, particularly with regard to current from phase to ground, the case most common in practise.

The paper by Mr. Fitzgerald presents a method beautifully simple for applying differential protection to transmission lines. Differential protection has been developed to its highest perfection in England, and a general study of the English methods, difficulties and results is valuable to anyone interested in relays.

I should like to point out from a practical standpoint some of the difficulties that will be encountered before the carrier-current pilot system can be universally applied to large high-voltage networks. Judging from considerable carrier-current experience with all available present-day makes on extreme high-voltage lines it can be stated that at present existing relay systems are far more reliable than carrier-current installations.

In view of its extra cost, the carrier-current installation to be desirable must give superior performance. Some means must be secured to eliminate the phase-relation troubles mentioned in the paper, because the charging current on a 200-mi. 220-kv. line is often half as great as full-load current, and at low or medium loads may be more than the in-phase current at either end of the line, depending on operating conditions.

It is a perfectly practical condition to have more than 45 deg. between such currents for normal conditions. Lower-voltage networks have relatively little of such troubles.

Another difficulty is that the current in phase-to-ground short circuits greatly varies in power factor, depending upon the location and character of the trouble.

Relays at present in use for ground protection are so connected as to trip in a given direction selectively on as low as ¼ sec. and on the Pacific Gas & Electric system of some 5000 mi. of line, 60-kv. and above, last year, for over 1500 operations, there was no indication of a faulty operation of a ground relay.

Phase relays depending upon combinations of voltage and current do not present nearly so clean-cut a record.

Finally, the operating time must come down from the present standards,—a very great way down,—as a perusal of several of the high-tension papers presented will show.

Differential protection is one of the most desirable forms known, and outside the various split conductors and enclosed pilot wires used on low tension, the carrier system is the initial attempt to adapt it to high tension. It is to be hoped that it can be developed to overcome most, if not all, of its present limitations.

Philip Sporn (by letter): As pointed out by Mr. Fitzgerald, the differential method of protection of generator and transformer windings has become almost universal and is the only standard and proper method of protecting these important pieces of equipment. The use of the differential circuit in protecting buses has also come very prominently to the foreground within the last four or five years. Abroad, the differential scheme has been employed to protect transmission lines but it has never found very much favor here and in the main I believe this instinctive engineering act, if you wish to call it that, has been fully justified. If a pilot line is made more reliable than the transmission line, and it must be that to stand up under conditions that would cause the breakdown of the transmission line, then the cost involved becomes so great that economically it becomes prohibitive. If it is not to be built with the same degree of reliability then it is of no use to go to the scheme. The use of carrier eliminates the main reason why the pilot scheme has not found favor here up till now.

To those of us who have had actual experience in trying to obtain selective action on a loop involving four or five, and sometimes six, stations, by the use of reverse-power and induction-type relays only, and who have actually been trying to obtain another 10 cycles differential between two stations, and have known the disappointment that goes with chasing through a set of relay time settings only to find at the very end that there is one condition under which the apparently perfect set of settings would not work, the idea of getting a method of cutting down by one or two, the number of stations that would have to be made so to differentiate will certainly be welcome.

It is hoped that actual operating experience will bear out all the fond hopes that we have for this scheme. On this, as well as on the question of tests referred to by Mr. Fitzgerald, we may have something to place before the Institute within the next year or so.

One other aspect of the differential scheme of protection that ought to be pointed out is the lightning aspect.

Operating experience obtained within the last four or five years on systems where, under conditions of short circuit or flashover, currents in the neighborhood of 3000 to 5000 amperes can be pumped into the point of flashover on a transmission wire, has definitely shown that if the trouble is cleared within a certain minimum time, little burning, if any, will result. I think it can be definitely stated that on systems such as mentioned, if this time is kept below 1 to 1½ sec. no trouble need be anticipated. Further, if the time is made as high as 3½ sec., trouble is to be expected almost always. Now here is an arrangement that in a loop system allows the clearing of a case of trouble within a period say of $^1/_2$ to $^2/_3$ sec. The contribution of such a device to continuity of service, if it develops satisfactorily, is bound to be enormous.

L. F. Fuller: A protective gap is placed around the carrier-current trap so that surges on the transmission line will not pass through the trap but will jump the small gap and pass on. This gap is not shown in Figs. 2 and 11 of the paper.

A. S. Fitzgerald: Mr. Stauffacher has made reference to the speed of operation of this form of protective apparatus. In the first trial installation of this system no especial effort was directed toward attaining any great speed of tripping. We concerned ourselves mainly with an investigation of the operating characteristics of carrier current in this new field of application.

As Mr. Stauffacher indicates, the speed of tripping of this apparatus is not limited to the half-second mentioned in the paper, where reference was made to a circuit in which the overcurrent relays, which initiate the operation of the carrier-current equipment, were connected so as to control the filament voltage.

Substantial reduction in time can be obtained if, instead, we connect these relays so that they complete the plate-voltage circuit instead of the filament supply. This is now being done in the case of the equipment which the paper describes. The filaments are run continuously, but since the plate voltage is not normally applied to the tube, no emission can take place except when the protective equipment is actually brought into operation. The life of the tubes, of course, depends largely upon the length of time during which there is emission from the filaments.

Mr. Wilkins restricts his remarks to the conditions which are encountered when this system is applied to very high-voltage lines. It is assumed that he has principally in mind systems operating at 220 kv.

Mr. Wilkins entertains some doubt as to the reliability of carrier-current equipment. The number of carrier-current communication installations now in service in the United States on systems up to 132 kv. must exceed 200, and this figure surely

suggests that a high order of reliability has been attained. The amount of carrier-current equipment at present installed on 220-kv. lines does not seem sufficient for final conclusions to be drawn as to the results which can be obtained at this voltage. Mr. Wilkins will also appreciate that the function which the carrier current is called upon to perform, is, in the present application, very much simpler than that necessary in the case of carrier-current telephony. There is no question of calling, nor are there any problems of modulation. Furthermore, the transmission of carrier is restricted to the simplest case of a single length of line instead of having to carry right across a complicated network.

The author finds himself in agreement with Mr. Wilkins when he points out that the application of carrier-current protection to 220-kv. circuits will involve the consideration of conditions not met with at lower pressures, and especially in respect to his remarks on the advantages of ground relays in comparison with phase relays. It is not unlikely that the ultimate solution will be found in a carrier-current system envisaging ground faults principally, if not exclusively.

The question of current-phase relation is, perhaps, rather too involved to discuss through the present medium but it may be pointed out that the curve given in Fig. 10 is the result of specific design based upon an estimate of the probable general condition. It is possible to furnish different characteristics if circumstances should require them.

The author shares with Mr. Sporn the hope that this system may ultimately prove to be a real help in the operation of large power systems.

SYNCHRONOUS CONDENSERS[1]

(Alger)

Del Monte, Cal., September 15, 1927

R. H. Park: Usually, synchronous condensers are purchased for power factor correction and voltage regulation. It is sometimes desirable, however, to purchase additional condenser capacity in order to secure greater stability either in steady operation, or during transient periods of instability, such as are occasioned by short circuits and sudden load changes.

The ability of a condenser to improve stability under steady conditions depends upon the values of its synchronous and transient reactances, although the relative importance of these two has not yet been convincingly established. It also depends upon the type of voltage regulator employed and on the speed of response of its exciter.

On the other hand, the ability of a condenser to improve stability during system transients occasioned by short circuits is determined largely by the amount of leading current which the condenser can supply to the system, and thus by the transient reactance and the speed with which the excitation system can vary the condenser field voltage over a wide range. If insufficient range of exciter voltage is available, the advantage derived by effecting the available voltage change quickly will be slight.

Thus, where stability considerations are important, it may be desirable to provide an exciter of considerably greater voltage range than for normal application. Also, it may be desirable to use special condensers designed for low transient reactance. I should like to ask Mr. Alger, therefore, which is economically more desirable, to secure low transient reactance by a special design of condenser, or by using a standard condenser of larger size.

M. W. Smith: Mr. Alger has brought out some interesting and practical considerations in the design and operation of synchronous condensers. A timely plea has also been made for standardization of requirements and characteristics which affect design proportions. Standardization is, of course, desirable in all classes of apparatus, but for obvious reasons, synchronous condensers probably offer more possibilities in this respect than any other large rotating apparatus. Considerable movement in this direction can be made without impairing the quality of the apparatus, and which will result in benefits to both the operating companies and the manufacturers.

Past experience has usually shown that the variable having most effect on synchronous-condenser design proportions, is the ratio of lagging to leading kv-a. capacity. Mr. Alger has proposed several methods for obtaining increased lagging kv-a. capacity from machines of standard proportions. All of these methods may be applied in special cases, but the use of suitable reactors is about the only method proposed that can be offered as a general application. It seems doubtful if even this method can be applied economically in most cases. It has been noted that where large percentages of lagging kv-a. capacity are specified, machines of special and abnormal proportions have usually been supplied after all conditions were considered. This results in units which are comparatively expensive and inefficient. Every effort should, therefore, be made to keep the requirement for lagging capacity down as close to 50 per cent of the leading kv-a. capacity as possible. This consideration should be kept in mind in the operation and layout of power system as far as economic considerations will permit.

P. L. Alger: Answering Mr. Park's inquiry, I believe that the most economical way to secure abnormally low transient reactance in a synchronous condenser is to use an oversized machine with a standard field, but a special armature. The per cent reactance is nearly the same for all standard machines, so that by merely using the next larger standard rating, a proportional decrease in reactance is secured. However, this larger machine will have more armature copper and larger slots, than are necessary for the new rating, and so a further reduction in the per cent transient reactance can be secured by using a special armature winding with shallower slots. The saving in cost of copper and insulation here will more than offset the cost of the special features. By these means, the transient reactance can be reduced about 10 per cent faster than the corresponding standard rating is increased. By using field poles, shorter and narrower than standard, additional gains could be made, but at greater expense, and with a greater loss of efficiency.

1. A. I. E. E. Journal, December, 1927, p. 1330.

STATIC STABILITY LIMITS AND THE INTERMEDIATE CONDENSER STATION[1]

(Evans and Wagner)

Del Monte, Cal., September 15, 1927

F. E. Terman: An illustration that indicates the thoroughness of the authors of this paper is their discovery of the fallacy of the classical belief that the maximum angle of stable operation of a network is the angle of maximum power of transmission. In reality the angle is a little greater, permitting stable operation slightly beyond the point of maximum power. The difference between the old and the correct belief is not great, but its discovery was a real achievement.

One of the most uncertain factors in stability computations is the characteristic of the load under change of voltage. Some investigators have assumed a load that drew constant power and reactive power as the load voltage changed (approximated by a motor load), while others have assumed that the load was such as to maintain the load voltage constant at all times (equivalent to assuming a receiving synchronous condenser of infinite capacity.) The former assumption gives computed results worse than are actually to be expected, and the latter leads to an optimistic result, considerably better than can be realized in practise. The actual load is one that allows the voltage to drop during disturbances, and as the voltage drops, the power demands of the load become less, and the power factor of the load improves. The power does not drop as fast as it would with a load consisting of an admittance of constant value, so that the admittance-load

1. A. I. E. E. Journal, December, 1927, p. 1423.

characteristic used by the authors is a correct assumption only in so far as the improvement of the power factor of the actual load can be considered as off-setting the less favorable power characteristic of the real load. When the voltage fluctuation is small it is likely that a constant-admittance load would give about the same result as a practical load, but for large fluctuations, as 25 per cent, this almost certainly would not be the case.

Actually, we don't know much regarding the reactive and real power drawn by the load when the voltage is suddenly changed. I should like to see some of the power people make tests, such as dropping the voltage at a distributing center first by 5 per cent, then 10 per cent, and so on, noting the change of power and power factor caused by each drop. Such information would be invaluable for stability studies, and could be obtained without creating an appreciable disturbance to service. At present we can get correct results for the conditions assumed, but we have very little idea how correct our assumptions are.

In applying the results of the paper to present transmission practise several points must be kept in mind. The results presented in Fig. 21, giving the effect of a midpoint condenser on the power limits neglect charging current, which is an important factor on lines over 200 mi. in length. In interpreting this figure, one must also remember that it is only the lower curves that apply to ordinary conditions. This is because the ratio of voltage at the midpoint of the line to the internal voltage of the generator (not terminal voltage) is normally less than unity. Boosting the midpoint voltage abnormally high by the use of a condenser is in effect increasing the average transmission voltage and this will obviously raise the power limit. The intermediate condenser when used to make the midpoint voltage higher than the terminal voltages will give the large increase in power limit shown by Fig. 21 in the upper curves, but this is gained at the expense of a poor voltage distribution along the line, and in a large measure could be obtained by the alternative method of omitting the condenser and raising the terminal voltages a little, thus keeping a flat-voltage distribution. Such a flat distribution would not put as high a voltage on the midpoint of the line as would be present when the synchronous condensers were used.

Figs. 22 and 23 have been computed for an actual transmission line that has charging current, and indicate that a large intermediate condenser is required to raise the stability limit very much. An ordinary condenser has around 100 per cent synchronous reactance (*i. e.*, sustained short-circuit current equals full-load current). On the basis of this, the curve marked 100 per cent reactance represents an installed capacity of 100,000 kv-a. and the 25 per cent reactance curve represents 400,000-kv-a. installed capacity. An inspection of Figs. 22 and 23 indicates that an intermediate condenser in the order of hundreds of thousands of kv-a. is required to give large increases in the power that can be transmitted over the line.

Even with the use of large condensers, the gains that could be expected on an actual transmission system would be much less than indicated in Figs. 22 and 23 because these figures are based on the assumption of infinite-capacity bus at the receiver. An infinite bus is one which will keep its voltage absolutely constant during all kinds of system troubles, and no actual bus comes anywhere near being an infinite bus. Dr. Bush and Mr. Booth[2] made some computations which showed that condenser equipment giving about 40 per cent increase in limit under the assumption of infinite bus at the receiver, would give less than half of this gain in power limit with a finite bus approaching ordinary characteristics. There is a large difference between the actual finite bus and the theoretical infinite bus of the curves.

To sum up the situation, it is evident that this paper indicates that the increase of power limit that can be obtained by the use of intermediate synchronous condensers of usual characteristics is small unless the intermediate condenser has a capacity of at least 100,000 kv-a. and preferably two to four times this amount. Using standard condensers of 400,000 kv-a. capacity the increase in power limits with a finite receiver bus would probably be less than 40 per cent.

This is a discouragingly small gain for the price it costs. It seems that in all probability the next step lies in the development of low-impedance condensers used in conjunction with quick-excitation systems. A 100,000-kv-a. condenser having 10 per cent leakage reactance with an instantaneously acting exciting system would give the same increase of limits as a 1,000,000-kv-a. condenser of present standard type with the usual excitation speed. Such a condenser at the midpoint, with another at the receiving bus, would do wonders toward increasing the power limit of a transmission system. A condenser of this type at the receiver would give the practical equivalent of an infinite bus, and one at the midpoint would be substantially equivalent to a condenser of zero reactance. Fig. 23 shows that the gains would be very substantial.

R. D. Evans: With reference to Dr. Terman's discussion regarding the maximum angle for which systems are stable we did not wish to emphasize the point unduly because for commercial systems the increase is not very marked. However, when several synchronous machines are being considered it is very important to have the right type of limit. In this connection it may be observed that the maximum delivered power will in general occur for an angle less than the maximum stable angle; so that for practical calculations of power systems, the methods commonly in use are, according to our views, correct.

With respect to the discussion on the characteristics of the loads, we feel considerably more optimistic than Dr. Terman. We have made tests on our shop system in order to determine the variation of real power and reactive power for changes in the supply voltage and have found that the methods described in the paper apply. Also we have taken a number of power-company systems and segregated the load into relatively small units and studied their characteristics. We have found their variation of real power and reactive power with respect to voltage and combined them, and obtained the results described in Figs. 6 and 7. Finally, we have taken a static load, one of constant impedance, and analyzed it from a theoretical standpoint, considering the variation in real power and reactive power, with angle and voltage as worked out in Appendix II of the paper. For these conditions also the check was very good. Of course all who are interested in the theoretical calculations would welcome any kind of test which would give the fundamental experimental data on this subject.

With respect to the curves showing the increase in power, I wish to emphasize the point, that the curves have been plotted on a conservative basis. For example, the condensers were not located at the theoretically most advantageous point, but were placed at the middle of the line regardless of the effect of the terminal equipment. The curves for 220 kv. and 110 kv., plotted in Figs. 15 and 18, are based on constant voltage on the high-voltage side, and no attempt was made to take advantage of any over-voltage.

There is another phase of this problem with respect to the static limits, which is important. The method and calculations as presented apply directly only to the limits that obtain with fixed excitation of the machines. It has been demonstrated that quick-response excitation systems under the control of suitable regulators will increase the loads which can be carried. This was first pointed out by E. B. Shand and first experimentally verified during 1925 by the authors of the present paper. We wish to make it clear that we have not included in the figures given in this paper any advantage which will accrue as a result of quick-response excitation systems.

P. L. Alger: There are two points in this paper that I wish to discuss. In the first place, the authors have concluded that under certain conditions, stability of a transmission line can be maintained beyond the impedance angle, and the exact limiting

2. TRANSACTIONS A. I. E. E., 1924, p. 72.

angle up to which stability can be maintained, depends upon the relative inertias of the sending and receiving-end machines.

This conclusion seems to be unreasonable, as the static stability limit is reached when the machines pull out of step so slowly that inertia effects should be negligible. What the authors have shown is that when the angle of maximum power is reached, and passed, the motor begins to slow down, the line current increases, and the generator also slows down until such time as the governor of the generator prime mover operates. If the generator inertia is sufficiently small, it will obviously retard faster than the motor, and the two ends of the line will stay in step at first. On the ninth page, the authors say—"The system as a whole will retard, reducing the frequency, but this will be taken care of by the automatic governors."

The fallacy in saying that the machines are stable beyond the angle of maximum power, lies in the assumption that the governor is able to reaccelerate the motor after it once has begun to slow down. What actually happens is that the motor and generator retard together until they have acquired an appreciably lower velocity than normal, and then the governor feeds more power to the prime mover, and the system breaks apart. The additional power reaccelerates the generator, and supplies additional power to the line, but this extra power is dissipated in extra copper losses, and the actual power received by the motor decreases. As the motor will not reaccelerate until it receives more than the power it had when it went out of step, and as it is impossible for the line to deliver more than the amount of power it did when the motor began to slow down, the motor can never be restored to speed, and so the system is unstable.

Thus, the authors have shown that when a system becomes unstable, the sending and receiving ends may stay in step while retarding up to the time the governor operates, instead of falling out of step immediately, as might have been thought. This conclusion is interesting, but is of no practical importance.

The second point that I should like to bring out is the matter of the additional condenser capacity required in order to secure a given additional amount of power over a transmission line. This ratio of additional kv-a. of installed condenser capacity to additional kw. output obtainable is the fundamental factor that determines whether the scheme of an intermediate condenser station is or is not of practical economic importance.

Fig. 21 of the paper presents curves showing the additional percentage output obtainable by using intermediate condensers, assuming a transmission line without resistance and without charging current. On this ideal basis they show that about 50 per cent additional kw. can be sent over a line by this means, on the basis of the reasonable values of $\frac{E_T}{E_A} = 0.9$, and $\frac{Z_C}{Z_L} = 0.6$. From equation (42), and the other data given, I calculate that this result is obtained by adding 200 per cent of the original line capacity in condensers. Or, in order to obtain each kilowatt of additional line capacity, it is necessary to add 4 kw. of condenser capacity. Under the different assumptions used in Fig. 22, approximately the same ratio is shown. Here, the authors have assumed no line losses, an infinite bus at the receiver, a very low generator reactance, and they have not stated clearly how they allowed for the important effects of the line charging currents.

Thus, the results of the paper indicate that under practical conditions it will be necessary to install much more than four times as much condenser capacity as there is obtained additional line capacity; and so it does not appear that the scheme of the intermediate condenser station is of great economic value at the present time.

In spite of my feelings that the results they have obtained are not of immediate practical importance, I feel that the authors have performed a great deal of useful work in their study of this important problem, and that their paper will be of great value as a basis for further study.

R. D. Evans: The question of the limiting stable angle is quite involved. The criterion selected was that the system be forcibly displaced slightly from the normal condition for which the mathematical solution of the voltage, power and circuit conditions were satisfied. In order to determine whether or not the system pulls out at that point one must consider the transient and on account of the inertia and electrical loads one end tends to move more rapidly than the other. The possibility concerning which Mr. Alger is doubtful, (if I understand him correctly), is the fact that if the angle is increased slightly the machine that is leading may tend to slow down more rapidly, and therefore to stay in step.

Concerning the question as to the effect of the governor, it is necessary only to point out that when the angle is decreased, more power can be transmitted.

With respect to the second point brought out by Mr. Alger, the amount of condenser kv-a. that has to be added to a system to increase the amount of power which can be transmitted, I do not know the exact basis used for his computations. If one considers the case of a system operating close to the static limit without a condenser and the ratio of the increase in reactive power to the increase in real power and then compares the corresponding conditions with a condenser operating near the static limit, it is true that one will obtain a relatively large increase of reactive kv-a. for each kilowatt increase.

The practical condition, however, is this: the system will be operated appreciably below static limit and under these conditions the increase in condenser capacity for each kilowatt of increased power which can be transmitted is not nearly so large as indicated by Mr. Alger. Furthermore, the total magnetizing kv-a. required by the system is actually less when supplied by machines which are distributed than when all condensers are at the receiving end. If the means for supplying reactive kv-a. are distributed an increase in the power limit is secured. So, for the practical conditions one can increase the power transmitted and also increase the margin of stability and thus arrive at the best compromise as to the increase of condenser capacity on the system and the amount of power to be transmitted, and in no event will one closely approach the static limits.

R. W. Mackey (communicated after adjournment): The paper by Messrs. Wagner and Evans covers the cases of the static stability limits of straight-line transmission with one or two intermediate condenser stations, but where the system is more complicated or in the form of a network with condenser stations distributed on the network the mathematical method becomes cumbersome and practically impossible of solution.

The case I have in mind is the 220-kv. interconnection now being carried out in the east between the Philadelphia Electric Company, The Pennsylvania Power & Light Company and the Public Service Gas & Electric Company of New Jersey.

During the last four months we have developed the mechanical model demonstrated by Mr. Evans for application to the quantitative solution of such complicated systems.

In the above case we were more concerned with the transient stability under short circuit and worst switching conditions than anything else but our solution also gave information as to static conditions.

I should like to elaborate on the methods used but this whole investigation is being prepared in the form of a paper to be presented by Messrs. Bergvall and Robinson.

At this time I mention this as it may be of interest for members to know that we are tackling the more complicated systems and expect to obtain great help from the analogous synchronous mechanical system.

C. F. Wagner: Dr. Terman's remarks regarding the increase in power occasioned by the use of an intermediate condenser station are substantially correct and in accord with our point of

view. We concur with his remarks regarding the desirability of low-reactance condensers and quick-response excitation. In interpreting the curves showing the improvement on actual power systems, several facts must be born in mind. These results show the static limit of lines in which the amount of copper was dictated by loads considerably below the static limit, that is, for loads determined by the transient limit. If the static limit were determining, larger conductors would have been chosen for the line without condensers and still larger conductors for the line with condensers. A comparison under these conditions, paying due regard to the increased financial burden occasioned by larger conductors, would have been much more favorable for the intermediate condenser.

Mr. Alger questions our ideas regarding the limiting angle and states that our conclusions seem unreasonable to him. He cannot agree that the inertia has anything at all to do with the maximum angle at which the system can operate. Perhaps a discussion of a simple system consisting of a synchronous generator and synchronous motor with a connecting impedance in which the resistance is equal to the combined reactance of the line and machines, may clear this point. For the first case let the inertia of the generator be extremely large and the inertia of the motor, small. This corresponds to a small motor connected to a large system through an impedance. It is evident then that no action of the motor will be reflected in the main system. The power input into the motor will then increase until the angle reaches 45 deg., beyond which it will decrease. The limiting angle in this case is equal to the impedance angle. This is the more familiar arrangement and one from which the idea that the angle could not exceed the impedance angle was probably derived, but conclusions drawn from this illustration cannot be applied indiscriminately to other cases. Consider now that this synchronous motor is acting as a generator and is feeding power into the large system through such an impedance. Again, any phenomena in the generator will have an inappreciable effect upon the large system, whether it be voltage change or change in phase position of the rotors. With increasing angle the power input into the system will increase until an angle of 45 deg. is reached, beyond which the power will decrease. But what occurs to the output of the generator? This increases continuously even beyond 45 deg., reaching a maximum at 135 deg. While the input into the system decreases beyond 45 deg. the increase in copper loss is more than enough to overcome the decrease in system input. Now the generator responds, not to input into the system, but to its output. The system will be stable up to an angle at which an increase in angle no longer produces an increase in output, which in this case is 135 deg.

It is hoped that this discussion will make more lucid our conception of what occurs when the limiting angle is reached. While this discussion considered only limiting cases in which the inertia of one of the machines was extremely large it should be clear that for machines with more nearly equal inertias the difference in operation is one of degree only. These ideas have been verified by shop tests in which, citing from random, we have been able to obtain angles as large as 140 deg. No particular effort has been made to obtain larger angles.

I am at a loss to understand Mr. Alger's criticism of Fig. 22, when he states that no line losses were included in the calculations and we had not clearly stated how we had "allowed for the important effects of the line charging currents." The development of the formulas presented in the paper were premised on the most general type of circuit including both lumped and distributed constants. The general form of the equations are given in equations (1) and particular reference was made to distributed constants in the paragraph preceding equations (3). Mr. Alger's remarks regarding the efficacy of condensers should be tempered by the same considerations mentioned in the discussion of Dr. Terman and our reply. We do *not* agree with Mr. Alger that the scheme of the intermediate condenser station is not of great economic value at the present time, but on the contrary see wonderful possibility in its utility for the transmission of large blocks of power over great distances.

EQUIPMENT FOR 220-KV. SYSTEMS[1]

(Jollyman)

Del Monte, Cal., September 15, 1927

Harold Michener: Mr. Jollyman speaks of the dirt and the salt accumulation on insulators. Our experiences indicate that the only way to maintain satisfactory service is to clean the insulators as frequently as necessary, that frequency being determined by a study of local conditions.

R. J. C. Wood: An insulator string is most likely to fail when wet by a fog. At this time the distribution of voltage is undoubtedly determined by leakage currents rather than by the condenser effect of the unit.

That, I believe, is entirely true where there is not much lightning trouble; but the effect of grading a string is to increase the lightning flashover value.

This grading should be more valuable to those building lines in the East and mountainous parts, where lightning is more frequent than it is here.

HIGH VOLTAGE OIL CIRCUIT BREAKERS FOR TRANSMISSION LINES[2]

(Wilkins and Crellin)

Del Monte, Cal., September 16, 1927

J. D. Hilliard: In this paper the importance of high-speed switching in increasing the stability of the transmission network is emphasized, and the conclusion is drawn that the oil circuit breaker is the only piece of dependable apparatus at present obtainable, or likely to be obtainable in the near future which can be used for this work.

To this conclusion I think no exception will be taken by those familiar with the operation of interrupting devices for electric circuits, including the so-called vacuum switch.

For years it has been recognized that speed was one of the chief factors in the construction of an efficient oil circuit breaker, but it was also recognized that the oil breaker must be of sturdy construction. By speed I mean the total time elapsing between the beginning of the short circuit and the complete interruption of the current.

The fact that one breaker may have a shorter arcing period than another may be of small moment so far as system stability is concerned, if the total interrupting period of the two breakers is practically identical, and when test data are given both the total short-circuit duration and arcing duration should be given, if a logical comparison is to be made.

Whether a shorter arcing duration is favorable to one breaker as compared to another breaker will depend on the speed of break (per break unit) of the two breakers, and the number of breaks in series; in other words, it will depend upon the total quantity of gas generated in the two breakers.

Tests with plain-break contacts, operating under identical conditions, have shown that the two-break breaker is quite likely to generate less gas than 6, 8 or 10 breaks in series. It is a fact as the authors have pointed out, that a current-limiting resistance in series with the arc, greatly reduces the severity of the arc. This coupled with the light weight and high speed of the moving parts explains the superior action of small potential fuses where the current flow is limited by resistors. When, however, an attempt is made to apply the same kind of a device to an oil circuit breaker where the resistance must be shunted in circuit when the breaker operates, it is found that many difficulties arise, not the least important of which is keeping down the cost of the breaker equipment.

1. A. I. E. E. Journal, September, 1927, p. 877.
2. A. I. E. E. Journal, December, 1927, p. 1340.

The authors have given the speed of a General Electric Company FHKO-36-33 C, 115-kv. oil circuit breaker as 5.5 ft. per sec. maximum at 300 amperes charging current. The interrupting capacity of this breaker for two O-C-O duty cycles is 3750 amperes at 115,000 volts, and since the speed of operation of this breaker is a constant of about 5 ft. per sec. at no load, plus a variable dependent upon the load interrupted, the figures given, although correct for the quoted load, are not half their real value when the breaker is interrupting its rated interrupting capacity.

Moreover, one can expect a longer arc when interrupting a small charging current than that obtained when interrupting the full interrupting capacity of the breaker, so that taking both these factors into consideration, one would expect the full-rating arc duration would be less than half as long as the charging-current arcing duration.

It is also a fact that the speed of operation of the explosion-chamber breaker is a maximum shortly after the end of the contact rod clears the throat bushing,—that is, the speed is a maximum at the time of the long arc, and this means the smallest quantity of gas during that period. This should be compared with the breakers having the maximum spring tension and maximum speed during the early stages of arcing when the gas generated per unit of arc length is small. In one case we have a maximum speed decreasing to a minimum; in the other case we have a minimum speed increasing to a maximum.

The quantity of gas generated at constant speed of contacts for a given arc duration varies approximately as the square of the speed, because the arc likewise varies directly as the speed.

When the above facts are considered, it is easily seen why the explosion-chamber breaker produces such a small quantity of gas, and why it has such a high interrupting capacity.

It is not clear to the writer why high speed of separation is necessary when interrupting line charging current or load currents of small magnitude, because under these conditions the line should be fairly stable.

For heavy short circuits, however, high speed would be advantageous, and it is under these conditions that the explosion-chamber breaker is at its best, and its strong construction enables it to stand repeated interruptions without damage.

The Canton tests were 26 and 30 consecutive operations on the two breakers, without examination of the oil or contacts, and both were in first-class condition at the end of the tests and could, undoubtedly, have duplicated the performance and still have been in good operating conditions. It is probable that 100 such operations would still have found them able to carry their rated load and interrupt their full rated interrupting capacity.

It is to be expected that the earlier explosion-chamber breakers would not be developed to the degree found in the modern breakers, that the years of operating experience would result in breaker improvements, that better constructional methods, better materials and better workmanship would be built into the later breakers just as there have been improvements in the automobile in the same period.

It is unfortunate that the various curves mentioned in Messrs. Wilkins and Crellin's article are not available at this time, and, therefore, no comparison can be made on the time of relay action, breaker trip, and breaker interruption of circuit.

In the article no mention is made of tank pressures as a function of speed of interruption, and but little has been said concerning voltage rises due to the same cause.

Fairly high impact pressures must be expected in the oil when high-speed interruption takes place, although at the time there may be no evidence of pressure in the air space above the oil. This high impact pressure is due to the substantial incompressibility of the oil, the mass of the oil and the instantaneous generation of a gas in fairly large volume. It acts, of course, to stress the tank and unless the seams are well made, may result in their being opened up, whereas with a slower operating breaker the stresses may be considerably less.

The voltage rise, from substantially instantaneous interruption, is likely to be a real problem, and in such apparatus excessive voltages have been observed during tests, and the steep wave front makes it impossible to obtain an oscillographic record with the ordinary oscillographic apparatus.

Peak records can, of course, be obtained by a surge recorder, or by the cathode ray oscillograph, and such records have shown surges considerably in excess of any mentioned by the authors. It is not impossible that under special conditions, voltage surges of 25 times the applied volts may be observed.

The authors mention the fairly high power factor in a short circuit to ground. This is, of course, due to the ground resistance and was to have been expected. It also largely accounts for the fairly easy condition for ground interruption on a system having a grounded neutral. The fundamental requirements, as laid down by the authors, are not so impossible of achievement by the high-voltage oil circuit breaker as would appear at first glance, and with the exception of (1) *i. e.*, O-C-O cycle of operation = 0.2 second, can I believe be approximated if there is a demand for such a breaker and the purchaser is willing to pay the price of development.

The testing of oil circuit breakers by the manufacturer and user is of great importance, and the General Electric Company's engineers are not only making such tests daily at the factory, but have taken every opportunity to make tests upon operating systems.

The General Electric Company strongly recommends the publication of full detail information on such system tests. Such information will be of incalculable value to transmission companies and manufacturers of oil circuit breakers, and will act to largely dispel the skepticism concerning circuit-breaker operation and rating which now exists. The factory tests are considered of so great importance that a new testing generator has been constructed and will have been given preliminary tests by September 10th, 1927.

This generator is the largest testing generator ever constructed, and is expected to give a short-circuit kv-a. of nearly 600,000. Space has been provided for additional generators of the same or larger capacity, and it is expected that if connected to the Mohawk-Hudson system ultimately a short circuit capacity of considerably in excess of 1,000,000 kv-a. will be available at both low and high voltages.

The testing installation has been made very complete, and comprises both resistors and reactors for current limitation, bomb-proofs in which to test the breakers, a separate oscillograph and assembly building and ample grounds surrounding the test plant, so that the test men and observers may be at a safe distance from the breakers tested to destruction, and every breaker which can be stressed to that extent will be so tested. The testing equipment will, of course, be as complete as it can be made, and instruments are provided for measuring all factors affecting the interrupting capacity of the breakers that it is possible to measure.

In the thousands of tests made with our factory testing generator during the past six years, we have observed phenomena far more severe than any ever recorded by us on tests made upon transmission systems. We have observed arc lengths in excess of the charging-current arc lengths observed by the authors; and it is my opinion that our testing conditions are more severe than obtained on any transmission system in existence today, if we except the operation of a transmission system at the instant of a lightning stroke.

These observed test values are used in the design of new breakers, and it is these observations which determine the physical dimensions of our breakers. It is because of our observations that the break distances of General Electric breakers are made consistently greater than those of any other manu-

facturer; and although we realize that it may be a rare occurrence for an arc to be drawn the full break distance, it is also realized that a sustained arc in an oil circuit breaker is a serious thing and may result in the destruction of the breaker, and must be guarded against at any cost.

The authors state that the manufacturers positively "refuse to give a guarantee on performance." I think that a consideration of the facts will show that statement is not exactly correct. While the General Electric Company does not guarantee their breaker rating, they do stand back of their breakers and will continue to do so.

At a joint meeting of the Oil Circuit Breaker Section of the Power Club and the Oil Circuit Breaker Subcommittee of the N. E. L. A. a year ago, all of those present were unanimously agreed that a manufacturer could not guarantee interrupting capacities of oil circuit breakers, because the interrupting capacity at any given instant depended on system, maintenance and operating conditions which were entirely beyond the control of the manufacturer.

The Oil Circuit Breaker Subcommittee of the N. E. L. A., therefore, unanimously agreed that three alternative clauses be recommended to the manufacturers, but expressing a preference for the following clause:

"Because system, maintenance, and operating conditions are beyond the control of the manufacturer, interrupting capacities of oil circuit breakers cannot be guaranteed, but this does not relieve the manufacturer of his contract obligation to deliver oil circuit breakers having interrupting capacities as specified."

Acting on this recommendation of the Oil Circuit Breaker Subcommittee of the N. E. L. A., the General Electric Company adopted this clause as recommended. Under this clause, the company is bound by a legally enforceable contract to deliver a circuit breaker having the specified rating, and evidence that the circuit breaker does not have the rupturing capacity specified would force the company to replace the circuit breaker with one having the specified rating, or would make the company liable for damages for breach of contract.

There may be uncertainty in the minds of some manufacturers and some users as to the meaning of kv-a. interrupting capacity. Is it the interruption at unity power factor, or at approximately 90 deg. lag or lead? Is it the interruption of the current on an otherwise isolated bus system, or is it interruption on a system having a connected load with shunt reactance and electrostatic capacity? Is it on grounded or ungrounded systems?

As far as the General Electric Company is concerned, and based on engineering information that has become available from field and testing department experience, the General Electric Company's published interrupting rating includes all the conditions mentioned above and the General Electric Company will continue to publish ratings on this basis unless future development makes modification necessary, in which case, the published ratings will state that fact.

The writer regrets that the tests did not include repeated interrupting tests at or near the rating of the breaker so that observations of contact burning could have been made.

H. E. Strang: In discussing oil circuit breakers the term "Speed of Operation" is frequently used and unfortunately at times loosely applied with the net result that some confusion exists as to just what thought this expression is intended to convey.

From the standpoint of system stability, interest is centered around the total time required for opening a circuit from the instant the trip coil is energized until the arc is finally broken, rather than the actual speed in feet per second at which the contacts may part.

An analysis of the opening characteristics of various kinds of breakers will reveal the fact that one type of motor operator which imparts a comparatively high speed in terms of feet per second to the contacts after they have started moving, has an inherent time delay in the tripping mechanism itself, which makes the dead time, or the time from energizing the trip coil until the contacts part, nearly twice as long as in the case of breakers operated by other types of motor or solenoid mechanisms.

Supposing that there may be a balance in favor of the breaker operated by this former mechanism of some few half cycles of arcing time, the total duration of short circuit may be much longer than in the case of a breaker whose contacts travel more slowly, but operated by a mechanism with a shorter inherent dead time. It is this feature which is essential when considering the application of oil circuit breakers from the standpoint of their effect on system stability.

It is regretted that the curves which have been presented showing the opening characteristics of various types of breakers were not plotted on the same basis, that is, from the time the tripping impulse is delivered to the trip coil.

Figs. 9 and 10, showing the opening time of a General Electric FHKO-36-110-kv. breaker seem to answer a commonly raised question regarding the effectiveness of explosion chambers at low currents. In this case while opening only 300 amperes which is some 8 per cent of the breakers' interrupting rating, a definite acceleration is given to the contacts which amounts to an increase of about 2 ft. per sec. in maximum velocity over the no-load speed.

That this effect is consistent in reducing the arc length over the entire range of a breaker's rating is also apparent from the published results of the Canton tests where in the case of one explosion-chamber breaker during a series of 30 tests, ranging from 23 per cent and 83 per cent of its interrupting rating, the arc length varied from but 40 per cent to 20 per cent of the stroke.

As the authors have stated, the ultimate interrupting capacity of these large breakers may not be definitely known. It is believed, however, that if there is any uncertainty in the ratings it is on the side of conservatism, and that it is not necessary to apply factors of safety to the ratings of breakers which have been subjected to extensive factory tests, the results of which have been substantiated by field tests such as those made at Canton.

M. M. Samuels: May I be permitted to add some constructive suggestions? First is the question of the parts which the users and manufacturers should respectively take in the further development of breakers.

Now, it is not possible, nor is it necessary for an operating man to known as much about all of the detail problems of breaker construction as a manufacturer's engineer. But the operating man knows what he wants the breaker for, what service it has to perform, he knows this better than the manufacturer; he has to make it perform as part of a system, and he soon finds out wherein it fails so to perform.

Advice along these lines from operating men should be eagerly sought by manufacturers. The manufacturer should realize that the customer is not just kicking for the fun of it; but that when he kicks there is something wrong; and then let the experts get busy and find out what is wrong.

The needed spirit of cooperation on the part of the manufacturers is beginning to show itself here and there, and has no doubt been a contributing factor of considerable importance in the great strides which the manufacturers have made in very recent years in circuit breaker developments. But more of it is needed.

Another suggestion which may be made is that future tests should be carried on under actual operating conditions. So far, elaborate preparations have been made for each test. Contacts were cleaned and adjusted, mechanisms greased, relays cleaned, new oil placed in the tanks, etc. Under operating conditions this is not done every day, and in most cases it is not done often enough; and yet breakers have to operate.

I should suggest that in the future tests be made on breakers

after they have been in service for some time, without making such preparations. In other words, without telling the breakers that they are going to be tested.

As to the concluding requirements of Messrs. Wilkins and Crellin, I may state that the one requiring a maximum of one kv. is to my mind not of great importance. I will grant that the great amount of power required to close some breakers is due to very clumsy mechanism designs. The bell-crank artist is still among us, and the manufacturers have not as yet learned that a good switch designer is not necessarily a good mechanism designer, and that none of the switch mechanisms shows the ingenuity and beauty which may be observed in some of the automatic machinery which they have in their own shops. However, give me a good breaker, and I do not care if it takes 5 kw. to close it.

The suggestion that it should be possible to install a breaker without skillful mechanics likewise seems to be going somewhat too far at the present. It is true that breaker mechanisms should be simplified rather than be made more complicated; but I doubt if it ever will be possible or even desirable to eliminate the skillful mechanic in the installation of breakers.

Let me add a concluding remark. It will be necessary to reduce the cost of breakers in the future. The breaker today represents the limit to electrical development, not only insofar as it sets a maximum to the amount of energy that can be safely switched, but also economically. Many a prospective development cannot be put through because the cost of switching makes the whole development uneconomical. It will not be sufficient in the future to spend half a million dollars on research to find out that the tank steel has to be ½ in. instead of ⅜ in. thick, and to spend another half million to find out that two more pounds of copper will have to be added to the contact, or that structural-steel tops are in some cases preferable to cast-steel tops. To our shame it must be admitted that the ratio of results to development expense is very low in the circuit-breaker field, and it is development expense which makes the cost of breakers so prohibitive.

Radical discoveries and inventions are needed, if the industry is to progress. A beginning has already been made, and one hint is already mentioned in the paper as to what might be expected in the future. I am referring to vacuum switching. But o far that is only a hint; and in general there are very few inventions of ingenuity and importance on record in the whole history of switching.

The industry seems to have been immunized against an attack by the bacillus of invention. Messrs. Wilkins and Crellin are right, therefore, in their statement that we are doomed to depend on oil breakers for a good long time to come; and that the improvement of them, to which I may add the reduction of their cost, is of immediate importance.

L. C. Williams: "Speed" is a much misinterpreted word. The electrical engineer talks in terms of cycles for interrupting a circuit or clearing a fault whereas the mechanician speaks in terms of velocities of the moving elements.

Let us consider switching time in two parts, (1) the time required to overcome inertia and acquire acceleration of blades and measured from the time the relay contacts close until the arcing tips separate and (2) from that point until the arc is broken and the fault cleared.

The sum of the two times is important from the standpoint of system stability and all operating engineers desire it cut to an absolute minimum.

The second consideration is of vital importance in switch performance as high blade velocities contribute to a short duration of arc and improvement in switch reliability.

Our present methods of control work somewhat at cross purposes. To gain high blade velocities is usually at the expense of burdensome control equipment and markedly increasing the time to get under way.

What we want is an improved control equipment which permits the switch to operate rapidly and minimize the overall operating time.

Slow-motion pictures taken of the mechanism of heavy duty switches emphasizes this necessity and likewise afford an accurate means of calibrating switch speed curves.

W. S. Edsall: The paper points out the desirability of clearing trouble from the transmission line in the shortest possible time. Several curves are given showing oil circuit breakers of the 110,000- and 220,000-volt class, giving the time required from closed position to the contact-breaking point and arc-clearing point. It is noted that on one 110,00-volt contact-break type of breaker it required about 0.125 sec., or 7½ cycles on a closed position to opening of the contacts. About 4½ to 5 cycles additional were required to break the arc of the changing current. Contrasted to this in a desire to point out that records are available showing the performance of the American Brown Boveri Electric Corporation BO-60, 110-D oil circuit breaker handling short circuit in the order of 400,000 kv-a. where the complete O-C-O cycle was made in approximately 14 cycles. This time is taken from the instant the contacts touched on closing plus the relay action time for reversal of motion of moving member springing the arc and complete interruption.

This type of oil circuit breaker is of the 10-break or multiple-break type. It is of the comparatively slow-speed design. In no case was the speed of the moving element higher than 2.8 ft. per sec.

The statement is made that records have been taken on 110-kv-a. oil circuit breakers both on 2-break and 6-break types, with speeds varying from 4 ft. per sec. to 15 ft. per sec. per contact and a range of arcing time from 12 cycles on the slow speed to 2 cycles on a higher speed. This would infer that the higher-speed breakers clear the arc more quickly than the slower-speed.

It is also stated that "the important point often overlooked is that the high-speed breaker clears the disturbance in much less time with much less damage both to system and to the breaker."

Records are available showing the type BO-60, 110-D, American Brown Boveri Electric Corporation oil circuit breaker, performing on O-C-O cycle with short circuit in the order of 500,000 kv-a. wherein it is shown that very slow speeds will interrupt the arc in the same time of arcing as with higher speeds. It was shown one one test that the average speed was approximately 5.5 ft. per sec. on opening and on the second O-C-O of the operating duty the speed was reduced to approximately 1.4 ft. per sec., approximately 50 per cent of normal, yet the time of arcing remained the same.

It is our belief that, contrary to the general thought, the introducing of greater speeds alone does not necessarily give better oil-circuit-breaker operation. It is our belief that the use of the 10-break multiple break with slow moving mechanical parts presents many advantages. Due to slow speeds there is no racking of mechanism at the end of the stroke, whether on closing or opening,—only simple torsional accelerating springs are used. There is no quick-break mechanism of any kind, hence no triggers, latches nor springs.

Furthermore, it has also been demonstrated on tests that close to 700,000 kv-a. the use of the 10-break breaker gives pressures less than 20 lb. per sq. in. in the tank.

There have been some misconceptions as to the length of arc per arc and the total arc length in breakers of the 10-break type. It is true that if the speed of the moving element were the same in the 10-break type as in the usual 2-break type the total length of arc in the 10-break type might exceed that of the 2-break type. However, the speed of the BC-60 American Brown Boveri high-voltage oil circuit breaker is comparatively low, so that the total length of arc is very little if any greater than would be experienced on a 2-break type under the same conditions. It is definite that the length per arc is much less in each of the 10 arcs than the length of each arc in a 2-break type.

The paper makes a reference to the use of resistance in conjunction with one multiple-break oil circuit breaker. Reliable resistance-type multiple-break oil circuit breakers have been built in Europe for many years. Resistance is mounted within the tank at a point such as to clear it from precipitating carbon and low-dielectric oil at the bottom of the tank. The usual method is to connect resistance in shunt with 4 or 6 of the multiple breaks, leaving from 2 to 4 of the multiple breaks in series. Upon interruption the arcs which are shunted by the resistance are immediately made unstable, thereby leaving very high resistance in series with 2 to 4 arcs. This gives a high resistance against the recovering voltage, cuts down the current flow and acts to diminish the time of arcing. Breakers of the 110,000-volt class with interrupting rating of 500,000 kv-a. of the resistance type have been built and successfully operated for a number of years.

In summarizing we would point out that the high-voltage oil circuit breaker as manufactured by this corporation will probably come nearer meeting No. 1 requirement on the eighth page of the paper than any others on the market today. This requirement is that the complete O-C-O cycle shall not be more than 0.20 seconds. Interrupting-capacity tests in the order of 500,000 kv-a. show a time of 0.22 sec. average. The operating mechanism for these breakers is of the motor type, simple in construction and requiring very small current for operation. The power demand is less than 1 kw.

The breakers are of very simple construction, such as will enable them to go through many operating cycles with very little inspection.

Philip Sporn (by letter): I am pleased that the authors have tackled a question that has not been given the attention it deserved, and that is the question of oil circuit breakers and their effect on continuity of service in transmission networks. I think some work ought to be done also with particular reference to the effect on continuity of service of switching arrangements on high-voltage lines.

As a general rule a transmission line is planned and built by the transmission engineering department and when it is all over the job is given to the relay engineer to relay it. Sometimes he actually knows something about it a few months in advance of completion but it is very seldom he has much of a say in the arrangement of the line and the effect it will have on his various loop circuits. The fact that this additional line will make selective action almost impossible or, if it does make it possible, will introduce unusually high time settings on some of the lines, is not given very much weight and the problem is generally considered one of minor importance and one that a good relay engineer ought to be able to take care of. Of course where a double-circuit line between two points is involved, the problem is very very simple but very often the double-circuit lines do not materialize or where a line is laid out for two circuits, a simgle circuit only is installed and such a period may last for five years. The introduction of a pilot system of protection on transmission lines will materially ease the whole problem of sectionalization. It will particularly make possible the reduction in the time a fault is allowed to stay on the system and this will reduce to a negligible quantity not only the damage done during a fault but will also improve stability and will further reduce the trouble on customers' apparatus as a result of long surges on transmission systems.

Obviously if a carrier-current pilot system of protection is to be effective it has got to have a reliable means of coupling and Mr. Belt has shown[2] some of the devices that can be and are being employed today to obtain reliable and effective coupling. It is of course evident, that there is no sense in making large expenditures on a relay system such as a carrier-current pilot system that will cut down relay action on a single line from 2 or 3 sec. to ½ sec. if the breaker itself will take an equal amount of time to function in clearing a short circuit after the relay system has energized its trip circuit and this point has been brought out very well by Messrs. Wilkins and Crellin. As an example of this, refer to Fig. 10 where one of the phases of a breaker is shown taking about 0.27 sec. before opening. Now, compared to a relay action of 3 sec. 0.27 seconds is quite good but when dealing with orders of time of relay action of about 0.5 sec. 0.27 isn't quite so good.

With some of the conclusions of the authors as to the fundamental requirements of a circuit breaker, I agree; with others I differ quite radically. For example, I believe that the operating time for a complete "Open-Close-Open" cycle of operations can be materially raised above 0.2 sec. provided the opening time can be reduced say to a figure approaching 0.05 sec., or, as an outside figure 0.1 sec. There is no question that the ideal half-cycle of arcing time would be a highly desirable thing if it could ever be obtained but I cannot quite see why it is necessary to limit the power demand of the mechanism to 1 kw. I do not see that it is necessary to have the breaker designed so that it can be installed, adjusted and maintained by the average mechanic without oil-circuit-breaker technique. I would like to see them so designed so that they can be installed, maintained and adjusted and then stay put when worked on by the average mechanic who had some special training.

That it is highly desirable that a breaker shall be capable of completing more than two normal operating cycles before any inspections or adjustments are necessary, there is no room for argument. The wonder is that the present operating cycle was agreed upon and not rejected as utterly absurd by the operating people. I do not know whether 100 is at all essential but it ought to be of that order. For the present 40 or 50 would be good enough and I believe that if the operating engineers insist on it they will get it some day.

I again am in entire agreement with the authors in that the only way for an operating company to know today as to whether the breakers that it is buying or that it contemplates buying will or will not perform satisfactorily, on its system, is to test them. Some day breaker development will have reached the point where this will not be necessary but it does seem necessary today. That this happy stage will arrive by combining all of the good features now available in the designs of the several manufacturers as the authors so confidently expect, I am not at all certain; we have seen in other lines of endeavor developments involving combinations of the best feature of each that gave a rather queer result. The problem would seem to be rather to have each manufacturer develop his design or new designs to a point where he is certain and doesn't merely think that the breaker will do what he says it will do.

R. J. D. Wood: One of the oscillograms shows the current increasing on interrupting the charging current on the line. Mr. Crellin said this was contrary to the ordinary conduct of current on short circuit.

In testing Mr. Sorensen's vacuum switch, which was done by bringing a synchronous condenser up to speed on the system, disconnecting from the system, and throwing it on the switch and using it as generator, we had occasion to notice the shape of the short-circuit current during the time previous to the opening of the switch. Quite a number of oscillograms of short-circuit current were made, some of them showing the ordinary asymmetrical type but quite as many showed the short-circuit current increasing for the first few cycles.

E. A. Crellin: It was short-circuit current.

R. J. C. Wood: But a single-phase ground.

F. C. Lindvall: The authors mention the possibilities of the vacuum switch. We at the California Institute of Technology who have worked on the problem of breaking currents in vacua are quite gratified by this recognition, for not all operating engineers and oil-switch designers are convinced that some day

2. *Coupling Capacitors for Carrier-Current Communication,* T. A. E. Belt, A. I. E. E. Journal, October, p. 1051.

the vacuum switch may be a reliable piece of station equipment.

We feel that our optimism regarding the switch is justified, and that the fundamental idea of the switch is sound. Yet, as Mr. Crellin pointed out, the transition from a rather delicate piece of laboratory equipment to a reliable device for commercial service is a long step which presents numerous difficult technical problems; but fortunately, as more new work is done on the switch, many anticipated difficulties eliminate themselves.

Two such points the authors mentioned in their paper and should be discussed briefly. First, we have found that the extremely high vacuum which was originally assumed to be an obvious prerequisite is not really necessary. This interesting fact was observed in a general way in the earlier vacuum switches, but in order to obtain more definite data on this point a small switch was constructed. This model had butt contacts of ½-in. aluminum rod. An ionization gage located between the switch and the cut-off from the diffusion pumps served for measurement of gas pressure in the switch.

For convenience in testing, the duty cycle of this model consisted of short circuiting and immediately opening the short-circuit on the high side of a 15,000/220-volt 10-kv-a. transformer. The short-circuit current through the switch was 3.5 amperes and the potential across the switch after break was of course 15,000 volts. For the first 20 or 25 trials of the switch at a pressure of 2×10^{-5} mm. of mercury severe arcing resulted with consequent liberation of gas from the electrodes. However, the contacts were then in shape for proper switching and successful operation followed. In fact, at a vacuum of the order mentioned, an arc could not be drawn out to maintain between the contacts even with maliciously slow operation.

Several runs of 400 or 500 operations were made with the switch cut off the pumps with careful note taken of time and of changes in the vacuum. These pressure changes were then compared with leakage curves taken on the switch, and the interesting result was that the rise in gas pressure during the long switching runs followed very closely the curves of leakage coming from a faulty seal. In other words, the amount of gas given out by switching with clean electrodes was but little.

The switch functioned consistently and was apparently indifferent to existing gas pressures up to the order of 5×10^{-3} mm. Beginning at somewhat lower pressures decided flashing could be seen at each operation of the switch, but every time a successful break was made. As a matter of fact, the switch would break current satisfactorily with sufficient gas present to give a solid negative glow from a spark coil through a side discharge tube. Hence, to generalize from these results it follows that with outgassed contacts only a tolerably good vacuum, one which is relatively easy to get and easy to maintain, is needed for successful switching. Thus, at once, many of the troublesome details of high-vacuum technic are avoided, and in consequence the switch lends itself more readily to the ordinary methods of manufacture.

The second point mentioned by Mr. Wilkins and Mr. Crellin, that of operating the contacts within the vacuum chamber, has been simply and adequately solved through the use of flexible bellows, which makes possible moving the switch contacts through any required distance by any suitable mechanism. As a consequence the switch may be locked in closed or open position, a feature demanded by the operating engineer.

We have also found that extreme speed of opening is unnecessary in the vacuum type of breaker. Thus the contacts themselves may be simple and have low inertia. In turn, the operating mechanism may be of light construction, permitting the operating speed of the switch as a whole to be made extremely high. This speed, together with the characteristic first half-cycle break of current, will give a circuit breaker whose operation will no doubt be rapid enough to meet modern switching requirements.

A further desirable feature would follow in that the simplicity of the operating mechanism of a vacuum switch should allow an accuracy of adjustment which would result in more nearly approximating the simultaneous breaking of current in the three phases of the switch.

R. W. Sorensen: Reference has been made to the development of gas pressure tending to rupture switch tanks when a switch is open, and the question has been asked, does this phenomenon of pressure occur in the experimental vacuum switches when such switches fail to function properly and do not interrupt the current? It would be natural to expect in case of failure to interrupt the circuit that gases might be given off from the switch terminals in sufficient quantity to develop pressures that would cause an explosion or bursting of the chamber containing the vacuum switch. Experiments which have been made with the vacuum switch in which over 150,000 kv-a., single-phase has been interrupted by means of single-pole switches have failed to show enough gas pressure to produce explosion. Also, when circuits of this capacity have not been completely interrupted by the opening of the switch, the switch has withstood any tendency toward an explosion. In a few cases where the glass container for the vacuum chamber has broken, whether due to heat or mechanical injury, the parts of the glass container have not been thrown about so as to indicate an explosion, but have rather, simply dropped to the ground and done no damage; in fact, we have had less flying of glass than is often the case when an ordinary electric light globe is broken. As an indication of our confidence that no explosions occur, I may say that those of us who are working with switching in vacuum have so little fear of flying glass or other parts that we stand within a few feet of the switch in order to watch its operation when experiments are being conducted; in fact, we approach the switch much closer than has been considered safe with oil switches which may throw oil.

Another very favorable feature of the vacuum switch is the low voltage rise in the circuit at the time of break. For, though the vacuum switch always breaks the circuit on the first half cycle, we have found the voltage rise with the vacuum switch to be less than with the oil switch. The oil switches we have worked with usually hold the arc 8 or 10 half cycles. That is, there seems to be more rise in voltage on the circuit at interruption when it takes several cycles to make the interruption than there is when interruption is made during the first half cycle. Many times in our laboratory we have put one of our vacuum switches in a convenient 15,000-volt circuit capable of supplying current up to 150 amperes and have, by means of the hand-operating lever, opened and closed the switch rapidly, perhaps six or eight times per second. This we can do 25 or 30 times without distressing the switch in any way. I have never seen such a demonstration made with an oil switch. In fact, the amount of energy expended in the switch does not seem to be great, the actual drop across the arc at separation of contacts being probably less than 100 volts. This means that there is not available a great deal of energy at the place where it will destroy switch contacts. One of our small switches, the contacts for which are rods ⅜ in. in diameter, has been used to open a 15,000-volt circuit, the current in which varies from a small amount to 125 amperes, more than 4000 times and the contacts show no appreciable pitting. I feel that we may safely say, therefore, that a vacuum switch which has been properly tuned up for operation will give good service and be able to interrupt circuits almost an infinite number of times without damage to contacts.

I do not wish in any way to give an impression that vacuum switches are ready for the market. During the five years we have been working on the switch we seem to have made small progress. Each move, however, has been a progressive one and perhaps it will not take five years more to develop a switch which will have some degree of success in practical service on power lines.

In conclusion, I can reply to Messrs. Wilkins and Crellin by saying that we have developed a means for moving practical

circuits in a satisfactory way. We have also been able in an experimental way to fulfill requirements 1, 2, 3 and 4 as listed in their paper. Requirement No. 5 is the one we have not as yet been able to meet.

E. K. Sadler: We have just completed some over-all tests, at our factory, which approach Messrs. Wilkins and Crellin's specifications; and I would like to make a few remarks on that.

We have found it possible to obtain the following speeds without complicating the operating mechanism or subjecting the switch to excessive jar in operation. This switch was of the six-break type and the speeds given are the total for all six breaks.

We have obtained a velocity of 51 ft. per sec. when the arcing contacts break and a maximum velocity of 75 ft. per sec. at a point some inches beyond where arcing contacts break. Opening of switch requires only 0.089 sec. for full travel of blades, and an elapsed time of 0.16 sec. from energizing the trip circuit until the arcing contacts open. The total break equals 36 in.

As regards a switch jumping when the operating mechanism is mounted remote from the switch; this switch can move 2 in., back, forward, right, left, up or down and still operate perfectly.

J. P. Jollyman: From the standpoint of the engineer having to do with the operation of a power system, we are very much concerned with the effects of trouble on the power system. We want to get those troubles off the system as quickly as possible. We do not want to wait until the voltage of the system is reduced to a point where the duty on the circuit breaker is reduced. We want the trouble removed before service is impaired and whatever kind of switch it is will have to stand this quick service.

J. S. Thompson: (communicated after adjournment): It is of incalculable value to the manufacturer of oil circuit breakers to secure the findings of engineers who have so thoroughly studied the problems to be met in oil-circuit-breaker design and to have the result of these studies summarized in the requirements which they have laid down. These requirements are looked upon as supplementary to most of those outlined by Mr. Jenks of the West Penn Power Company, in the paper appearing in the 1924 Transactions of the A. I. E. E., p. 648.

With reference to requirement 3, it is possible that a statement that the mechanism should demand but a very small amount of power would be sufficient, but the exact reference to 1 kw. is presumably prompted by the fact that mechanisms are available which require no more power than 1 kw.

With regard to the discussion presented by Mr. Sporn, it would appear that his reference to the absurdity of the test duty cycle demand is based upon a tendency to look upon test rating as synonymous with normal operating ratings in circuit-breaker practise. In all other apparatus the test ratings to which the apparatus is submitted, for periods such as one minute, are far in excess of the operating rating and therefore it is possible that some adjustment should be made so that the circuit breaker operating twice under the A. I. E. E. test rating would operate comfortably at a reduced operating rating for the 100 or even the 1000 operating cycles referred to in requirement No. 4. We would draw attention to the fact that the N. E. M. A. rule for reduced interrupting capacities, under item E, suggests the ratio which these two ratings might bear to each other.

With regard to the discussion presented by Mr. Hilliard, the uncertainty regarding circuit breakers on the part of those best informed is indicated by the phrases: "It is quite likely"; "Not half"; "One may expect"; "It is probable"; "Could undoubtedly"; "May result"; "Is likely to be"; "It is not impossible."

Mr. Hilliard appears to assume that doubling the speed of the break would invariably double the length of the arc, and with respect to this assumption, we would draw attention to Figs. 4 and 10, showing arc durations of two-break and six-break circuit breakers under exactly similar conditions. These curves indicate a duration of arc of 0.045 sec. in the six-break circuit breaker and 0.15 sec. in the two-break circuit breaker.

There would appear to be an inconsistency in Mr. Hilliard's reasoning where he suggests that a greater quantity of gas is developed by high contact speed, whereas later in his discussion he states that high speeds are advantageous.

Mr. Hilliard indicates that high-speed interruption produces voltage surges and also impact pressures in the oil. If this is the case it would appear that voltage surges are a necessary concomitant of high-speed circuit interruption. But regarding tank pressure, it may be stated in support of multiple breaks that no Pacific Electric Manufacturing Company six-break oil circuit breaker tank or top casting has ever been damaged either under test or operating conditions, nor have tank and cover assemblies ever been forced apart.

Mr. Hilliard makes the point that the long break is of value and, recognizing this, the Pacific Electric Manufacturing Company provides that each one of the six breaks of its circuit breakers is substantially as long as each one of the breaks of the conventional two-break oil circuit breaker. Properly disposed multiple breaks can be considered as a grouping of two-break oil circuit breakers in series, and could not be assumed to draw arcs, per pair of breaks, as long as a single two-break oil circuit breaker. This fact has been put in practical application on a Pacific Coast operating system on which the failure of a two-break circuit breaker was remedied by placing a similar two-break circuit breaker in series with it, the two mechanically connected to operate simultaneously. But a further advantage of six-break circuit breakers is obtained by so disposing the breaks that the explosive effect of one arc tends to blast a volume of oil through the path of adjacent arcs.

With regard to the comment submitted by Mr. Strang, the factor of inherent time delay in the tripping mechanism is a vital one. In developing the motor-wound spring-operated mechanism devised by Mr. Wilkins, the engineers of the Pacific Electric Manufacturing Company gave this factor prime consideration, with the result that the inherent time delay in this control is satisfactorily brief. It is possible that the control referred to by Mr. Strang could be corrected to secure equally excellent characteristics.

E. A. Crellin: Everybody seems to have remarked about the power demand of the operator being limited to one kw. Mr. Samuel says, "Give me a good breaker and I do not care if it takes five kw. to close it." It is granted that it makes little difference to the switch itself how much power it takes to operate it so long as there is sufficient to get the contacts in or out in fast time. The limitation was added for another purpose and was included along with the other specifications to complete the list of requirements.

Let me point out what is involved in a large operator power requirement, especially in a breaker which requires practically the same energy to open as to close. I recently visited a substation in which there will ultimately be some fifty 60-kv. breakers and six or eight 220-kv. breakers, the most remote of which are 900 or 1000 ft. from the switchboard. If it is necessary to have operating currents on the order of 200 amperes at 125 volts, we are faced with a very great expense in storage batteries and control cables in order to hold up the operating voltage. It may well happen that a group of breakers will be simultaneously tripped, and if they require heavy operating currents to open, will force the installation of expensive equipment. Even with the gravity-opened breakers, it may well be that a large series of successive operations will lower the battery voltage to a point where further operation is impossible. The reason for imposing the limitation on operating power was to effect economies in installation. Such operators are available, and greatly to be preferred to those requiring 200 or more amperes.

Mr. Williams and Mr. Strang both have the same thought on the definition of speed. It is high over-all speed until the circuit

is cleared that we are after. If the actual time of contact movement is kept relatively high for reasons of switch design, then speed must be attained in the operating mechanism in order to bring down the total time from the closing of the relay contacts to the final interruption of the circuit. In this paper "speed" does not mean the rapid motion of parts so much as it does the rapid interruption of the circuit, no matter how attained. It is felt by the authors, however, that much higher contact speeds than those at present obtaining will be of great advantage not only in preserving system stability, but in easing the stresses within the breaker itself.

Roy Wilkins: Mr. Hilliard states that "for years it has been known that speed was one of the chief factors of an efficient oil circuit breaker." Nothing seems to have been done about it, however, until very lately.

With regard to the testing of breakers below their rating, it might be well to point out that most of the failures on operating tests including those at Canton have been very much below the breaker ratings.

Mention was made of the fact that substantially instantaneous interruption causes very great voltage rises. This was the original argument against oil circuit breakers and is as true today as it was in 1895. There are as yet, however, no commercial oil circuit breakers that even approximate instantaneous interruption. No one has any hope of getting under the first half cycle. Mr. Sorensen has noted no alarming voltage rise at one-half cycle. In this connection, as was pointed out in the paper, the circuit characteristics are the determining factor on such phenomena.

With regard to guarantees, there were last year in one State of the U. S. some twenty times as many law suits for damage due to defective transformers as there were due to oil circuit breakers: the same arguments hold for both as far as care and maintenance are concerned, yet no reliable manufacturer proposes to withdraw the transformer guarantee.

With regard to the meaning of interrupting capacity in kv-a., I am frank to state that I, for one, am doubtful of what it means, if anything. Several years of intensive study in both the field and factory have so far only strengthened this doubt.

Multiplying a voltage on the bus before trouble by the current in the first one-half cycle of arc after trouble has no physical meaning and so far as yet demonstrated no practical one.

With Mr. Strang we are in thorough accord; it is a performance that is desired. The particular mechanism required may in the end not even remotely resemble any of the present types. The effect of trouble on the system is important, the effect on the breaker incidental, though all too often it is the controlling factor.

In reply to Mr. Edsall, I wish to emphasize again that what the purchaser buys is equipment to separate an operating system from a fault,—the fault and the oil circuit breaker condition at the time are secondary matters. While slow speed may be good for the breaker it decidedly is not for the system.

Breakers must be built whose opening time is under 0.1 sec. preferably as low as 0.05 sec. and whose arcing time approaches closely the optimum of ½ cycle.

Executives have been busy in the past with other matters, but of late they are giving more and more time to interconnection and network operation and the effect of combinations of networks. Eventually they will learn that the reliability of the entire network depends on the ability of the circuit-interrupting equipment to function properly in less than the time required for the parts of the network to pull out of synchronism and such circuit-interrupting equipment will then be demanded and made.

The point and purpose of the paper is not an attempt to design an ideal circuit breaker but to outline the requirements.

There are at present two theories or methods of network operation,—one with relatively light ties in an extensive network where each load is fed from more than one source, and in trouble, the smallest practicable section is isolated. Such systems require fast relaying and insure continuous service and are represented by the Pacific Coast, the Southeastern and the North Central networks in the United States, all covering extensive territories.

The second method depends on a backbone with radiating feeders where large blocks of power are transferred from the general source to the loads and where outages are not expected on the main arteries. Such systems provide only emergency relaying on these main lines because their loss means the serious crippling of the system, and extremely fast operation would not be necessary. No such system exists today in practise on anything like the scale of the type given above.

ILLUMINATION ITEMS

By Committee on Production and Application of Light

PHOTOMETRY OF INCANDESCENT FLOODLIGHTS*

The Committee on Illumination of the Association of Railway Electrical Engineers in its report at the annual convention (October 25 to 26th) deals with the photometry of Incandescent Floodlights at considerable length.

Floodlight beams usually show visible traces of filament images which may cause erratic results if the area photometered at each reading is small. Therefore an integrating device consisting of a hemispherical shell with an opening one degree square (Which would be 20.94 in. by 20.94 in. for a test range of 100 ft.) should be used in the same general manner as an Ulbricht sphere. The opening is covered with a translucent material such as sandblasted glass. This averages out minor irregularities in the beam.

The photometer is set up at a distance of 100 ft. (or more) from the lamp to be tested. Observations are taken at approximately 100 stations uniformly spaced throughout the beam, and in addition a series of stations on eight equally spaced lines radiating from the axis. The position of the axis of the beam is estimated by visual observations on the edges of the beam and otherwise; it can be located more exactly only by actual test. The test procedure and method of calculating results are covered in very careful detail and tables are included to simplify the calculations.

The beam is considered to extend to where the candlepower drops to 11 per cent of the maximum candlepower value found in the beam. Suggestions for determining the total lumens in the stray light area (outside the beam) are given. The efficiency of the unit is expressed as the ratio of the beam lumens to the total lumen output of the incandescent lamp. The percentage of light produced by the incandescent lamp found in the stray field may also be given.

The Illumination Committee in its report has decided to use the following classification of floodlight beams:

Narrow beam —beam spreads up to 15 deg.
Medium beam—beam spread from over 15 deg. to 30 deg.
Wide beam —beam spread over 30 deg.
Special beam —unsymmetrical beams and others not falling in the above groups.

*See *Railway Electrical Engineer*—October 1927, page 315-319. Article supplied by Committee on Production and Application of Light.

Journal of the American Institute of Electrical Engineers

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Changes of advertising copy should reach Institute headquarters by the 15th day of the month for the issue of the following month.

1928 Winter Convention Will Offer Valuable and Important Papers

An A. I. E. E. Winter Convention of outstanding interest and importance is promised in the program planned for the 1928 meeting which will be held February 13-17 with headquarters at the Engineering Societies Building, New York City. Technical sessions of highest merit, lectures, inspection trips, medal presentations and social features have been planned which will surely draw a large attendance.

Technical Sessions

The technical papers and lectures will include as subjects dielectrics, operation of interconnected power systems, insulators, magnetism, electrical machinery, communication, automatic substations, control and protective apparatus, synchronizing devices and arc welding. Great interest is being manifested in the session on Tuesday morning, February 14, on the subject of operating interconnected power systems. This subject will be presented in papers by five outstanding engineering executives representative of different practises in five parts of the country. Prepared discussions will be presented by several other well versed engineers.

Telephone Communication with London

Telephone communication with the British Institution of Electrical Engineers meeting simultaneously in London, is to be one of the outstanding features of the convention. This event is scheduled for Thursday morning, February 16. This session will open with two papers on transatlantic telephony as announced in the accompanying tentative program.

Following these papers there will be an exchange of greetings over the New York-London radiotelephone circuit between Bancroft Gherardi, President of the American Institute of Electrical Engineers, and Archibald Page, President of the British Institution of Electrical Engineers. Greetings will also be exchanged between Dr. F. B. Jewett, Vice President of the American Telephone and Telegraph Company and President of the Bell Telephone Laboratories, in charge of the development work done in this country leading to the establishment of the transatlantic service, and Colonel T. F. Purves, Chief Engineer of the British Post Office, who has charge of the development work done in England in this matter.

Arrangements are being made for these exchanges of greetings to be heard by those present at the session of the A. I. E. E. in New York, and also by the members of the Institution of Electrical Engineers who will be having a regular afternoon meeting in London, simultaneous with the New York meeting.

Following this two more technical papers will be presented as shown in the program.

Lecture by Dr. Norinder

Dr. Harold Norinder of Upsala, Sweden, well known in this country for his studies of lightning discharges and other matters, will furnish one of the interesting points of the meeting. He will deliver a lecture in the session on the afternoon of February 14, his subject being "The Cathode Oscillograph as Used in the Study of Lightning and Other Surges on Transmission Lines."

Lecture by Dr. Swann

Another event will be a lecture on "The Earth's Electric Charge" to be given by Dr. W. F. G. Swann on Monday evening, February 13. Dr. Swann, who is Director of the Bartol Research Foundation of the Franklin Institute, is an entertaining speaker as well as a high authority on subjects pertaining to electrophysics.

Details of the technical sessions are published in the accompanying tentative program of events.

John Fritz and Edison Medals

Two of the most highly desired rewards for engineering accomplishment will be presented on the evening of Wednesday, February 15. The John Fritz Medal will be presented to General John J. Carty and the Edison Medal to Dr. William D. Coolidge. Details of the award of the John Fritz Medal were published in the November JOURNAL, page 1290. An announcement of the award of the Edison Medal is published elsewhere in the January JOURNAL.

Inspection Trips

Quite a number of inspection trips have been planned, most of which will be taken on Thursday afternoon, February 16, though some of the places may be visited at other times by prearrangement. Among the trips which are planned are those to the following places:

132-kv. cable installation at Hell Gate Station of the New York Edison Company

"Iron-clad" switchgear—a substation of the New York Edison Company having only this enclosed type of construction

System operators switchboard, Waterside Station, New York Edison Company

220-kv. switching station—Hudson Station of Public Service Electric & Gas Company

Hudson Avenue Station of Brooklyn Edison Company

Broadcasting studio of National Broadcasting Company

A-c. network switches of United Electric Light & Power Company

The Electrical Testing Laboratories

The Bell Telephone Laboratories

Dinner-Dance

That enjoyable social function, the annual dinner-dance, will be held on the evening of Thursday, February 16 in the main ball room of the Hotel Aster. This is an institution which needs no recommendation. It is sufficient to say that it will be held in the spacious Astor ball room, the meal will be excellent and one of the best dance orchestras in New York will furnish the music.

The Smoker

A delightfully informal event will be the Smoker to be held on Tuesday evening, February 14, in the Belvedere of the Hotel Astor. Every effort is being made to make the program for this evening unusually attractive and at the same time to eliminate the confusion and crowding which have occurred in some former smokers. The committee feels that this can be done and without an increase in the former price of $2.00 per person.

Reduced Railroad Rates

A special railroad rate will be available to out-of-town visitors to the convention under the certificate plan. Under this plan each person should request a certificate when purchasing a one-way ticket to New York. Presentation of this certificate at Convention headquarters will entitle the holder to half-rate fare for the return trip over the same route provided 250 certificates are registered at the Convention.

When purchasing tickets members or guests should advise their ticket agents that they will attend the A. I. E. E. Convention and should ask for the certificates. Families of members attending the Convention are entitled to certificates also. On a few limited trains the return tickets purchased at reduced rates will not be honored. Tickets must be purchased within a limited number of days prior to the meeting and return tickets must be used within a limited time after the meeting. The limiting dates depend upon the location of the purchaser. Information on this and other details may be obtained from ticket agents. Immediately upon arrival in New York, certificates should be deposited with the endorsing officer at Convention headquarters.

All Visitors Should Get Certificates

Everyone should obtain a certificate, whether he will use it or not, for failure to do so may deprive others coming long distances of the saving in railroad fare made possible by this provision.

Convention Committees

The plans for the meeting are being handled by the following general committee and subcommittees:

General Committee—G. L. Knight, Chairman; J. B. Bassett, H. P. Charlesworth, H. W. Drake, W. S. Gorsuch, H. A. Kidder, E. B. Meyer, L. W. W. Morrow and R. H. Tapscott.

Entertainment Committee—J. B. Bassett, Chairman; L. B. Bonnett, H. C. Dean, J. F. Fairman, A. H. Inglis, C. R. Jones, and A. H. Kehoe.

Dinner-Dance Committee—H. C. Dean, Chairman, A. B. Clark, C. R. Jones, J. F. Kelley and F. A. Muschenheim.

Smoker Committee—J. F. Fairman, Chairman; R. E. Dennis, H. W. Drake and W. S. Gorsuch.

Inspection Trip Committee—A. H. Inglis, Chairman; W. B. Kirke, L. W. McCullough, W. R. Smith and F. Zogbaum.

TENTATIVE PROGRAM OF 1928 WINTER CONVENTION

(The papers listed in this program, although all have not been definitely scheduled, will in all probability be in the final program).

Monday Morning, February 13

Registration
Committee Meetings

Monday, 2:00 P. M.

Electrophysics and Dielectrics

Technical session under auspices of Committee on Electrophysics, Vladimir Karapetoff, chairman.

Surge Impulse Breakdown of Air, J. J. Torok, Westinghouse Electric & Mfg. Co.

Investigation of the Influence of Internal Vacua and Ionization on the Life Duration of Paper-Insulated, High-Tension Cables, Alexander Smouroff, Electrotechnical Institute of Leningrad.

Approximate Method for Solution of Electrical Networks, E. A. Guillemin, Massachusetts Institute of Technology.

The Boltzmann-Hopkinson Principle of Superposition, F. D. Murnaghan, Johns Hopkins University.

Monday, 8:00 P. M.

Lecture

"The Earth's Electric Charge," W. F. G. Swann, Director of Bartol Research Foundation, The Franklin Institute.

Tuesday, 9:30 A. M.

Interconnection and Its Effect on Power Development

Technical session under auspices of Committee on Power Generation, W. S. Gorsuch, Chairman.

The following papers and discussion constitute a symposium on present-day practise and new developments of interconnection in various parts of the United States. Some of the points to be considered are: (a) Effect on Plant Capacity and Size of Generating Units; (b) Economics of Operation; (c) Operating Features; (d) Stability and Reliability; (e) Load Dispatching and Load Control; (f) Technique of Interconnection Operation; (g) Physical Facts as to Interstate Power.

The Conowingo-Hydro-Electric Project of the Philadelphia Electric Company's System—With Particular Reference to Interconnection, W. C. L. Eglin, The Philadelphia Electric Co.

Some Problems and Results from Interconnection in the Southeastern States, W. E. Mitchell, Georgia Power Co.

Some Aspects of Pacific Coast Interconnections, P. M. Downing, Pacific Gas & Electric Co.

Interconnection and Power Development in Chicago and the Middlewest, H. B. Gear, Commonwealth Edison Co.

Discussion of the papers and the subject of interconnection in general will be presented by the following:

Charles L. Edgar, Edison Electric Illuminating Company of Boston,
James Lyman, Sargent & Lundy, Inc.
A. C. Marshall, The Detroit Edison Co.
Farley Osgood, Consulting Engineer.
E. C. Stone, Duquesne Light Co.
L. W. W. Morrow, *Electrical World.*
W. S. Lee, Southern Power Co.
C. F. Hirshfeld, Detroit Edison Co.
G. N. Tidd, American Gas & Electric Co.
H. A. Barre, Southern California Edison Co.
F. A. Allner, Pennsylvania Water & Power Co.

Tuesday, 2:00 P. M.

Technical Session on Miscellaneous Subjects

The Saturation Permeameter, S. L. Gokhale, General Electric Co.

Manufacture and Magnetic Properties of Compressed Powdered Permalloy, W. J. Shackelton, Bell Telephone Laboratories and I. G. Barber, Western Electric Co.

Effect of Humidity on Dry Flashover Potential of Pin-Type Insulators, J. T. Littleton, Jr. and W. W. Shaver, Corning Glass Works.

The Cathode Oscillograph as Used in the Study of Lightning and Other Surges on Transmission Lines, lecture by Harold Norinder.

Tuesday, 8:00 P. M.

Smoker and Entertainment

Wednesday, 10:00 A. M.

Electrical Machinery

Technical session under auspices of Committee on Electrical Machinery, F. D. Newbury, Chairman.

Synchronous Machines—IV, R. E. Doherty and C. A. Nickle, General Electric Co.

Calculation of Armature Reactance of Synchronous Machines, P. L. Alger, General Electric Co.

Reactances of Synchronous Machines, R. H. Park and B. L. Robertson, General Electric Co.

The Thermal Volume Meter, C. J. Fechheimer and G. W. Penney, Westinghouse Electric & Mfg. Co.

Wednesday, 2:00 P. M.

Electrical Machinery

Technical session under auspices of Committee on Electrical Machinery, F. D. Newbury, Chairman.

Recent Improvements in Turbine Generators, S. L. Henderson and C. R. Soderberg, Westinghouse Electric & Mfg. Co.

Design and Application of Two-Pole Synchronous Motors, D. W. McLenegan and I. H. Summers, General Electric Co.

Heat Losses in the Conductors of a D-C. Armature, W. V. Lyon, E. Wayne and M. L. Henderson, Massachusetts Institute of Technology.

Effect of Transient Conditions on Application of D-C. Compound Motors, L. R. Ludwig, Westinghouse Electric & Mfg. Co.

WEDNESDAY, 8:00 P. M.

PRESENTATION OF JOHN FRITZ AND EDISON MEDALS

(See details elsewhere in this announcement).

THURSDAY, 9:30 A. M.

COMMUNICATION

Technical session under auspices of Committee on Communication, H. W. Drake, Chairman.

Transatlantic Telephony—The Technical Problem, O. B. Blackwell, American Telephone & Telegraph Co.

Transatlantic Telephony—The Operating Problem, K. W. Waterson, American Telephone & Telegraph Co.

Following these papers there will be an exchange of greetings over the New York-London radiotelephone circuit between Bancroft Gherardi, President of the American Institute of Electrical Engineers, and Archibald Page, President of the British Institution of Electrical Engineers. Greetings will also be exchanged between Dr. F. B. Jewett, Vice-President of the American Telephone and Telegraph Company and President of the Bell Telephone Laboratories, in charge of the development work done in this country leading to the establishment of the transatlantic service, and Colonel T. F. Purves, Chief Engineer of the British Post Office, who has charge of the development work done in England in this matter.

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A New Horn-Type Loud Speaker, C. R. Hanna, Westinghouse Electric & Mfg. Co.

Certain Topics in Telegraph Transmission Theory, H. B. Nyquist, American Telephone & Telegraph Co.

THURSDAY, 1:30 AND 2:00 P. M.

INSPECTION TRIPS

THURSDAY, 7:30 P. M.

DINNER-DANCE

FRIDAY, 10:00 A. M.

CONTROL AND PROTECTIVE EQUIPMENT AND SUBSTATIONS

Technical session under auspices of Committee on Protective Devices, F. L. Hunt, Chairman.

Automatic Control of Edison Systems, O. J. Rotty, United Electric Light and Power Co., and E. L. Hough, General Electric Co.

Protection of Supervisory Control Lines Against Overvoltage, Edward Beck, Westinghouse Electric & Mfg. Co.

1926 Lightning Experience on 132-Kv. Transmission Lines, Philip Sporn, American Gas & Electric Co.

Vacuum-Tube Synchronizing Equipment, T. A. E. Belt, General Electric Co.

Use of Condenser Type Bushing in Synchronizing, E. E. Spracklen, Ohio Public Service Co., and D. E. Marshall and P. O. Langguth, Westinghouse Electric & Mfg. Co.

FRIDAY, 2:00 P. M.

ARC WELDING

Technical session under auspices of Committee on Electric Welding, J. C. Lincoln, Chairman.

Effects of Surface Materials on Metallic Arc-Welding Electrodes, J. B. Green, Fusion Welding Corp.

Arc Welding—Influence of Surrounding Atmosphere on the Arc, P. Alexander, General Electric Co.

Arc-Welded Structures and Bridges, A. M. Candy, Westinghouse Electric & Mfg. Co.

Welding and Manufacture of Large Electrical Apparatus, A. P. Wood, General Electric Co.

Regional Meeting Held in Chicago

HAS EXCELLENT ATTENDANCE, PAPERS AND DISCUSSIONS

The meeting held in Chicago November 28-30 by the Great Lakes District was an outstanding one among regional meetings of the Institute. The large attendance was particularly noteworthy, over 900 engineers attending the technical sessions, including about 200 Student members of Branches in the District. These figures do not include an additional number of guests who were present at the dinner-dance held on the evening of November 29. All of the technical sessions drew a large attendance, showing that the papers presented were of great interest. A large number also took the inspection trips which had been arranged.

SESSION ON 132-KV. OIL-FILLED CABLE

The meeting opened on November 28 with a one-day program conducted by the Branches of the District, a full report of which is given elsewhere in this issue of the JOURNAL. On the next day, November 29, the first regular technical session was held and this session was devoted to a symposium on *132-Kv. Single-Conductor, Lead-Covered Cable.* The session was opened with an address of welcome by B. G. Jamieson, Vice-President of the Great Lakes District, after which H. W. Eales, as presiding officer, took the chair and the four parts of the symposium were presented as follows:

Introduction—Economics and Commercial Demand, P. Torchio.

Theory, Design and Development, L. Emanueli.

Manufacture, Inspection and Testing, W. S. Clark.

Installation, A. H. Kehoe, C. H. Shaw, J. B. Noe and D. W. Roper.

As part of his presentation Mr. Roper showed some very interesting motion pictures taken during installation of the cable in Chicago.

In the discussion following practically every discussor commented on the magnitude of the accomplishments which have resulted in the successful operation of this cable, and several pointed out the probability of the successful application of the principle to cables of even higher voltages. H. L. Wallau compared the over-all diameters of the old type of cable with the oil-filled cable, stating that with a maximum potential on a single-conductor solid cable of 80-kv. to sheath a maximum working stress of 150 kv. per in. would require an over-all diameter of 3.19 in. and would give a safety factor of 1.77; while the oil-filled cable with a maximum working stress of 160-kv. per in. would have an over-all diameter of about 3 in. and a safety factor of 3.5 to 4. As a definition of safety factor he used the ratio of the indefinitely sustained breakdown voltage to the operating voltage. Further he pointed out that possibly operating experience with the 132-kv. cable may prove that a factor of safety of 2 to 2.5 is liberal. This would bring 220-kv. cables into the 3-in. diameter class. He pointed out that the oil-filled cable costs $2.13 per kv-a. mile and that if experience proves that this cable may safely be operated at 220 kv. with the same ampere loading, the cost would be reduced to $1.28 per kv-a. mile. He mentioned that the cost of 66-kv. solid-insulation cable in Cleveland based on 35,000 kv-a. per circuit is $1.62 per kv-a.-mile.

J. B. Whitehead spoke of a certain statement made by Mr. Clark regarding a descending power-factor voltage curve indicating a negative ionization coefficient. Mr. Clark had stated that the descending curve might have been due to errors in

measurement. Dr. Whitehead pointed out, however, that his experiments had shown many such curves and that they are inherent in perfectly impregnated insulation when the temperature is above 40 or 45 deg. He was borne out in this contention by R. W. Atkinson.

W. A. Del Mar pointed out one unusual aspect of the installation of this cable,; namely, that the manufacturers concerned took such a large part in the engineering work connected with installation. In answer to this, Mr. Clark pointed out that the manufacturers' supervision was large because the cable is of a new design and he stated that in the future much less help would be needed from the manufacturers.

F. M. Farmer mentioned that the cost of this installation might seem high but that, if applied to higher voltages, the economic phase would be quite changed. He mentioned, on the other hand, that if the principle is demonstrated as sound it might mean that possibly the same principle can be applied at lower voltages than 132-kv. at considerably less expense.

C. F. Harding stated that the field of intensity within the dielectric of this cable not only changes with changing voltage but is quite different from the ordinary field and is actually in rotation. G. B. Shanklin said that he did not believe that cable with solid insulation can ever approach the operating record of the oil-filled cable and that from an economic standpoint the oil-filled cable will eventually be on equal terms with solid cable of the same voltage rating.

In answering a question K. W. Miller explained that the amount of oil which flows into the reservoirs when the temperature rises is the sum of the expansion of the oil in the core and in the insulation minus the volume resulting from expansion of the sheath.

H. R. Searing pointed out the large condensive reactance of this type of cable, mentioning its possible serious effect on voltage regulation.

A. H. Kehoe stated that the New York line was installed at a cost within the specified estimates and that he believed that in the future these costs will be reduced. D. W. Roper mentioned that the cost of the Chicago cable was $1,250,000, including conduit, cable, terminal towers, intermediate towers for oil reservoirs, Kenotron outfit and a reasonable proportion of transformers and terminals. He mentioned that the evacuating and impregnating process requires four or five days. The maximum number of men working in Chicago was 125, including 40 engaged in pumping and 10 representatives of manufacturers. He pointed out that in both the Chicago and New York lines there had never been any electrical failures in the cable or the joints. The only troubles have been oil leaks.

Session on Railway Electrification and Applications in Steel Mills

The second session held on the afternoon of November 29, B. J. Arnold presiding, was devoted to electrical operation of railroads, a storage-battery locomotive, mercury arc rectifiers and synchronous motors for steel mills. The first paper, entitled *Illinois Central Suburban Service; First Year of Electric Operation in Chicago*, was presented by W. M. Vandersluis. In discussing this paper A. M. Garrett mentioned that high-speed circuit breakers in substations feeding the railroad had opened between 400 and 500 times in one month and that none had failed to operate properly. A. J. Klatte of the Chicago Surface Lines stated that, although a decrease might have been expected in his company's revenue in the South side of the city following the electrification, the reverse has been the case and the revenue has increased on every car line touching, crossing or near the Illinois Central.

The next paper *Synchronous Motors for Driving Steel Rolling Mills* by W. T. Berkshire and H. A. Winne was read by Mr. Berkshire. H. V. Putman stated that his company has installed a synchronous motor on a cold strip mill which starts under 200 per cent of normal torque and over 100 per cent pull-in torque. He stated that unity-power-factor motors are ordinarily cheaper than 80 per cent power-factor machines, but this is not true of motors having a pull-out torque between 250 and 300 per cent. He stated that when no corrective kv-a. is required than a 90 per cent power-factor machine represents a desirable compromise. A written discussion by B. A. Behrend was read which pointed out several considerations which make the synchronous motor more desirable than the induction motor for slow-speed, low-starting-torque, non-reversible applications. F. C. Hanker stated that over 60,000 h. p. of synchronous motors in 38 units rated 300 h. p. and above are now used in the metal industries. He mentioned the fact that though in some cases a somewhat larger synchronous motor may be required to replace an induction motor, the cost per kw. of the synchronous machine is usually less. He mentioned a recent application of a synchronous motor for rolling-mill service consisting of a 4000-h. p., 2200-volt, three-phase, 60-cycle, 450-rev. per min. unit for driving a continuous billet-roughing mill.

The next paper, presented by Caeser Antoniono, was entitled *Operation and Performance of Mercury Arc Rectifier on the Chicago, North Shore and Milwaukee Railroad Company.* A written discussion by H. M. Hobart was read which among other things stated that on account of the heavy load carried by the rectifier mentioned in the paper it would appear that the cost of this rectifier should be compared with that of a 1500-kw. synchronous converter and not with a 1000-kw. converter. He stated that from our present understanding of the rectifier it would appear that the limiting condition would not be momentary peak loads as in the case of the converter but sustained heavy loads; it may be that while the synchronous converter has such limitations for this kind of service (monthly average load about 12 per cent of continuous rating), the rectifier may not need to be so limited. He pointed out also that the higher efficiency of the rectifier substation at larger loads is due exclusively to the increased transformer efficiency, because the rectifier efficiency is nearly constant at all loads. A written discussion by W. B. Anderson emphasized the lower building-construction costs necessary for rectifier substations than for substations built to house rotating apparatus. He stated that in a certain substation building which would cost $20,000 for converters, $5000 would be saved if rectifiers are installed. In mentioning the advantages of the rectifier Mr. Anderson pointed out that it is suitable for operation at any frequency and at different d-c. voltages. He also questioned Mr. Antoniono's statement that a larger number of auxiliaries are needed for a rectifier than for a converter.

F. D. Newbury urged that a further study be made of the fundamentals involved in rectifier operation. He thought it unfair to compare efficiencies on the basis of such low load factors as mentioned in the paper, stating that it is possible, particularly with automatic stations, to have fairly high load factors and that in such cases there would be no great difference in efficiency in favor of the rectifier. He mentioned also that many large 60-cycle converters are operating under severe conditions with practically no short circuits. M. S. Oldacre emphasized the absence of noise and the ease of cooling the rectifier. A written discussion by Sidney Withington called attention to the largest installation of mercury arc rectifiers thus far made and the one instance of an entire city traction load being carried by this type of apparatus, namely five single-bowl rectifiers, rated at 1200 kw. each, recently placed in operation by the Connecticut Company in Bridgeport. After several months operation this installation has proved that it has numerous and important advantages over the rotary converter. B. G. Jamieson in speaking of future requirements made the point that there will be need for some satisfactory method of voltage regulation. He mentioned also the matter of back-fire and devices for suppressing it. Alfred Herzal, though agreeing that the rectifier has many advantages, mentioned that his company has had very

serious trouble from cooling water causing severe cases of electrolysis within the rectifier. He suggested the use of oil or air as a cooling medium. He stated that back-fire is not more serious than flashover in a converter. He also mentioned that the ripple in the d-c. output might cause trouble in certain instances by interference with communication systems. O. K. Marti claimed that back-fire properly controlled can do no harm to the rectifier or to the transformer. He pointed out that rectifiers developed by his company have no anode heaters and no motor generators for excitation as they are excited directly with alternating current. He mentioned that his company has developed rectifiers rated as high as 4400 kw. 600 volts.

Mr. Antoniono, in commenting on the discussion, stated that it is a fact that the rectifier in this case was expected to do the work that the 1500-kw. converters are doing in the same section of the road. He stated that a 1500-kw. rectifier had been considered but that the 1000-kw. unit was the largest the manufacturer could produce when it was bought. He agreed that the number of auxiliary devices will be decreased in the future. He mentioned that in operation in his company's stations no protective devices had been able to prevent flashovers of converters. He stated that he had experienced no electrolysis from cooling water in his station.

The next paper *Operating Experience with 125-Ton Storage-Battery Locomotive in Chicago Railroad Terminals* was presented by Edward Taylor.

Session on Power Systems

Subjects relating to power systems were covered in the third technical session on the morning of November 30, at which H. B. Gear was presiding officer. The first paper was presented by E. C. Williams, the author, and was entitled *The Chicago Regional Power System.* Commenting on this paper Mr. Gear pointed out that probably the most important feature is the interchange contract described in the paper. J. L. Hecht emphasized one of the points illustrated by the paper, namely, that having trunk-line interconnections between generating centers makes reserve capacity at any point available to the entire system. T. G. LeClair pointed out that a limit may be reached as to the amount of generating capacity which may be tied together and that such a limit is set from the economic standpoint by the cost of switch gear which increases very fast as more generating capacity is tied in. One plan of overcoming this increasing expense is to develop a system wherein the fault current is different from the load current. Such a system has been developed in Chicago by means of single-phase cables and transformers and isolated-phase switching stations. The fault currents are thereby limited to single-phase-to-ground faults and these currents are minimized by the use of neutral resistors.

F. C. Hanker mentioned another point in connection with circuit breakers and that is that if a fault can be removed from one part of a large interconnected system quickly enough to prevent phase displacement of another generating unit then the load will continue to be supplied without interruption. He mentioned that the principle covered by Mr. LeClair was being employed by several companies and that the amount of energy to be interrupted was limited to a certain value of kv-a. H. L. Wallau in commenting on this same thought stated that his company will not tie together lines of 100,000 volts and higher. All these lines are tied together only on the low-voltage side of their transformers. This limits the amount of power that may be developed in case of a transient fault and reduces the duty on the circuit breakers. B. M. Jones mentioned the necessity for careful consideration of contracts when generating centers are tied together.

The next paper *The Hall High-Speed Recorder* was presented by E. M. Tingley. C. I. Hall elaborated on some parts of the paper, covering particularly the matter of speed in starting of the record and arrangements for recording various special conditions. B. G. Jamieson in commenting on the speed of operation of this recorder brought out the need not only for an instrument which records very quickly but for a device which will also begin to clear a fault in a comparatively short time. In speaking in general of high-speed recording equipment F. C. Hanker mentioned the use of a newly developed oscillograph which begins operation within five or six cycles after the start of a fault and which employs a new type of watt-measuring element. This instrument has been of great service during the past two years on some of the Pacific Coast systems.

The next paper *The Application of Relays for the Protection of Power-Systems Interconnections* by L. M. Crichton and H. C. Graves was read by the latter author. In commenting on this paper H. D. Bradley drew attention to the fact that with the ground relay there is a possibility of improper operation unless the potential transformers are single-phase. He stated that on the 132-kv. cable in New York it was possible to use a directional ground relay which he believes can be set to operate at less than 100 amperes. L. F. Kennedy brought up the difficulty of protecting power transformers used in interconnections, particularly where these transformers are of the three-winding type and provided with tap-changing arrangements. He stated that growing importance should be given to protection against ground faults since with the higher voltages more ground faults occur than those of any other type and that nearly every short circuit eventually goes to ground. He thought that for parallel-line operation a balanced hookup with the necessary back-up protection provided by over-current relays is probably the most desirable scheme on account of its simplicity. F. D. Wyatt said that with balanced protection applied to a pair of lines it is usually assumed that they have the same impedance characteristics but that this is not always the case; when the lines have unequal characteristics it is necessary to make proportional adjustments of the relays. He mentioned malso the possibility of induced voltages being applied from external circuits to one of a good pair of lines.

In a written discussion E. E. George mentioned in connection with ground-relay protection the necessity for providing good current transformers and the advisability of testing them with current in one phase only after connections are completed. He said that the following were some of the results of operating experience which have been obtained by certain companies in his part of the country: (1) power-directional relays are of little value on interconnected systems; (2) impedance relays are reasonably satisfactory; (3) directional ground relays of the type using two current elements and connected as per Fig. 17 in the paper under discussion have been remarkably satsifactory; (4) selective differential relays have been very satisfactory when properly set and interlocked; and (5) directional volt-ampere relays have given some trouble due to variation in power factor relations.

B. M. Jones in a written discussion said that it has been his company's experience that complicated relay schemes are not desirable and that the schemes are made as simple and at the same time as small in number as possible. He mentioned a particular 66/132-kv. tie line on each end of which is installed two sets of over-current relays. One set of relays at each end are "fast relays" which operate in the case of trouble on the tie line, itself. The other set are "slow relays," which operate for trouble outside of the tie line and which are set slow enough to allow the relays of the two connected power companies to clear their own troubles unless these troubles hold on for a very long time in which case the slow relays break the tie. The ground relays are set fast and operate for trouble on the tie line itself. In commenting on this discussion Mr. Graves agreed that the setting of relays on complicated systems requires the skill of relay specialists. He stated that ground-relay protection, alone, is not satisfactory.

J. F. H. Douglas next presented the paper by himself and E. W. Kane, entitled *Alternator Characteristics under Conditions*

Approaching Instability. B. A. Behrend in commenting on this paper by letter drew attention to the method which he recommended, the Potier-Behrend zero-power-factor method for the determination of the regulation of alternators. He stated that this method through 28 years of use had proved fundamentally correct. He suggested that in designing a generator for a long transmission line the natural oscillation frequencies of the generator and of the system should be made different and that this would do much to improve operating stability. He agreed that alternators which will give greater stability should be built but said that it would be regretable if in striving for this end large generators will have to be built again with strong fields as they were years ago instead of strong (magnetically) armatures.

J. Strasser in a written discussion disagreed with the author's statement that there should be difficulty in plotting saturation curves at leading power factor from a theoretical standpoint and said that he had successfully used the Potier triangle for this purpose. He confirmed Mr. Behrend's statement that power stability depends upon the combined characteristics of network and generators. M. W. Smith pointed out that except in the case of very large high-speed machines no difficulties have been experienced in producing machines for any desired degree of stability under leading-power-factor operation. Such machines, however, have to be of special design. In commenting on this point F. D. Newbury mentioned that in one case approximately double stability was obtained at only a 10 per cent increase in cost.

Session on Communication

The last session of the meeting held on the afternoon of November 30 covered the subjects of telephone cable, telephone toll plant, vacuum-tube voltmeters and vacuum-tube rectifiers. With H. L. Hope presiding, the meeting opened with the presentation of the paper *Recent Developments in the Process of Manufacturing Lead-Covered Telephone Cable* by C. D. Hart. In commenting on this paper Mr. Newbar mentioned that the increased number of conductors in a telephone cable has been made possible by employing smaller conductors and thinner insulation, which results in increased transmission losses and these have been counter-balanced by improvements in other parts of the telephone system, such as transmitter, receiver, induction coil, loading coil, amplifier, etc. H. P. Charlesworth pointed out that there is now an all-cable route from Boston to St. Louis with various branches and that there are long stretches of cable in other parts of the country. He pointed out that the amplification necessary for telephone transmission is maintained on a stable basis, even though the temperature may vary considerably along the cable.

The next paper *Telephone Toll Plant in the Chicago Region* by Burke Smith and G. B. West was presented by Mr. Smith. G. S. Dring mentioned that a 1000-cycle system of ringing is coming into use on the longer toll circuits. This ring has the advantage that it is transmitted at practically the same efficiency as speech. H. S. Osborne pointed out the necessity for high amplification and limitation of distortion in transmission on cable circuits. He mentioned the use of voice-current relays for suppressing echo currents reflected from the ends of long cables.

The next paper was entitled *A Two-Range, Vacuum-Tube Voltmeter* and was written by C. M. Jansky, Jr., and C. B. Feldman, the former of whom presented it.

J. H. Kuhlmann next presented the paper *The Vacuum-Tube Rectifier* written by himself and J. P. Barton. H. S. Read in commenting on the paper made an interesting comparison, stating that the ordinary sounds which we hear, if reduced to proportional distances, would have a range from a half-inch to two-thirds the distance to the sun. C. M. Jansky, Jr., mentioned that many of the commercial rectifiers similar to the one described in the paper have high internal resistance and consequently poor voltage regulation. J. P. Barton stated that the voltage regulation in the rectifier described in the paper was approximately 23 per cent, though he recommended the use of inductances with less resistance. He mentioned that one reason for the poor voltage regulation of some rectifiers is that the designers do not take into account the direct current component which they must carry. He mentioned further that the high-voltage transformer also should have good regulation.

Inspection Trips

Four very interesting trips of inspection were taken by many of these at the convention. These trips were made to view first-hand (1) the 132-kv. cable installation of the Commonwealth Edison Company, (2) the electrified South Shore Line of the Illinois Central Railroad, (3) Crawford Avenue Station of the Commonwealth Edison Company and (4) a plant of the Wisconsin Steel Company.

Dinner Dance

A very enjoyable dinner dance was held on Tuesday evening, November 29. The only speaker of the evening was C. M. Newcomb, who spoke on "The Psychology of Laughter." After this lecture dancing was enjoyed until a late hour.

Special Institute Meeting

A special meeting of the American Institute of Electrical Engineers was held at the Drake Hotel, Chicago, on Tuesday afternoon, November 29, 1927, at 2:05 o'clock.

President Gherardi called the meeting to order and stated that the purpose of the meeting was to consider the adoption of a resolution which had been prepared by the counsel of the Institute and approved by the Board of Directors, authorizing an amendment of the Certificate of Incorporation of the Institute with the object of holding the Annual Meeting hereafter during the Annual Summer Convention. He then referred to the requirement of the Constitution regarding a quorum for a meeting of this nature.

National Secretary Hutchinson reported that a Special Committee on Proxies had been appointed by President Gherardi, consisting of Messrs. R. F. Schuchardt, Chairman, Ralph H. Rice, and H. E. Wulfing, and that this committee had presented a report to the President showing that 506 proxies in legal form had been received and that these proxies, in addition to the large number of members present, more than met the legal requirements of a quorum.

The following resolution as prepared by the Institute's counsel was then read, and upon motion of Mr. H. P. Charlesworth of New York, N. Y., seconded by Mr. E. B. Meyer of Newark, N. J., was unanimously adopted.

RESOLVED, that the Certificate of Incorporation of American Institute of Electrical Engineers be amended by providing that paragraph Seventh thereof, now reading as follows:

> "Seventh. The date for holding its annual meeting shall be the third Tuesday of May in each year."

shall hereafter read as follows:

> "Seventh. The date for holding its annual meeting for the year 1928 shall be Tuesday, June 26, 1928, and thereafter shall be such date as shall be fixed in the By-Laws."

FURTHER RESOLVED, that the President or a Vice-President and the National Secretary or the Assistant National Secretary of the American Institute of Electrical Engineers be and they hereby are authorized to execute and file a certificate of such amendment, as provided in Article IV of the Membership Corporations Law of the State of New York.

All the business specified in the call for this special meeting having been concluded, the meeting thereupon adjourned (and immediately reconvened under the chairmanship of Past-President B. J. Arnold, as one of the sessions of the Great Lakes Regional Meeting, a report of which appears in this issue).

F. L. HUTCHINSON,
National Secretary.

Future Section Meetings

Cleveland

Today's Science, Tomorrow's Engineering, by L. A. Hawkins, General Electric Co. Electric League Room, Hotel Statler, 8:00 p. m. January 19.

Power Plant Development, by C. F. Hirshfeld, Detroit Edison Co. Electric League Room, Hotel Statler, 8:00 p. m. February 16.

Columbus

Illuminating Meeting. January 27.

Modern Trend in Large Generating Apparatus, by F. D. Newbury, Westinghouse Electric & Mfg. Co. Film, entitled "From Coal to Electricity." February 24.

Erie

Recent Developments in the Art of Communication, by S. P. Grace, Bell Telephone Laboratories, Inc. January 17.

Commercial Aviation, by W. B. Stout, Stout Metal Airplane Co. February 21.

Ithaca

Traffic in Radio Communication, by F. H. Kroger, Radio Corp. of America. January 26.

Lynn

Motion picture, entitled "Age of Speed." 42 Centre Street, W. Lynn. January 11.

The Age of Man, by Prof. R. S. Lull, Yale University. Illustrated. Ladies' Night, Pythian Hall, Market Street, Lynn. January 20.

Hydroelectric Power Developments in the South, by W. E. Mitchell, Vice-President, Georgia Power Co. 42 Centre Street, West Lynn. February 13.

New York

Interconnection of Power Systems, by Alex Dow, President, Detroit Edison Co., and Farley Osgood, Consulting Engineer. January 13.

Niagara Frontier

Simple Electric Transients and Traveling Waves, by Prof. V. Karapetoff, Cornell University. Technical and musical program. Ladies invited. January 13.

Latest Developments of Welding, by C. L. Ipsen, General Electric Co. February 10.

Pittsburgh

Symposium on A-C. Network Systems, by C. T. Sinclair, Byllesby Engg. & Management Corp., and H. R. Searing, United Electric Light & Power Co. Talk by Bancroft Gherardi, National President. January 10.

The Engineer in Industry, by W. S. Rugg, Vice-President, Westinghouse Electric & Mfg. Co. February 14.

Pittsfield

Steam Power Stations, by F. S. Collins, Chicago. Stanley Club Rooms. January 24.

Floods and Flood Control, by Dr. Frank Bohn. Masonic Temple. February 7.

Heaviside's Operational Calculus, by Dr. E. J. Berg, Union University. Stanley Club Rooms. February 21.

St. Louis

Important Small Materials Used in the Telephone Industry, by G. S. Rutherford, Western Electric Co. January 18.

Superpower Transmission, by Robert Treat, General Electric Co. February 15.

Sharon

Raising the Submarine S-51, by Lieut. Commander Edward Ellsberg, U. S. N. Moving pictures. January 7.

New Developments in Supervisory Control, by R. J. Wensley, Westinghouse Electric & Mfg. Co. Moving pictures and demonstration. February 7.

Vancouver

Visit to Fire Dispatch Installation. January 10.

Students' Night at University of British Columbia. February 7.

New York Section Meeting on "Interconnection of Power Systems"

"Interconnection of Power Systems" will be the subject of the January 13, 1928 meeting of the New York Section of the A. I. E. E. Two speakers will cover the subject from the following viewpoints: *Concerning Utility Connections*, by Alex Dow, President, Detroit Edison Company, and recently elected President of the American Society of Mechanical Engineers; *Interconnections in the New York-Philadelphia Territory*, Farley Osgood, Consulting Engineer, New York. The meeting will be held jointly with the Metropolitan Section of the A. S. M. E. in the Engineering Auditorium, 29 West 39th St., New York at 8:15 p. m. Friday, January 13, 1928.

"Review of Scientific Developments of 1927" Before New York Electrical Society

On the evening of Thursday, January 26, 1928, the members of the New York Electrical Society will have the pleasure of hearing a "Review of the Scientific Developments of 1927." Dr. H. Clyde Snook, now consulting engineer, but for many years on the staff of Bell Telephone Laboratories, will give the talk. It will be accompanied by many demonstrations for which apparatus is now being gathered from scientific centers all over the country. This review of the wonders of 1927 is the second annual meeting of this type given before the Society and from the interest manifested in the 1926 review, it should draw a record audience. Dr. Snook combines the master showman and gifted speaker, intimately in touch with the scientific field. The New York Electrical Society extends an invitation to all members of the A. I. E. E. to be present on the 26th as its guests. The meeting will be held in the Engineering Auditorium, 29 West 39th St., New York City at 8:15 p. m.

A. I. E. E. Nominations

The National Nominating Committee of the Institute met at Institute Headquarters, New York, December 15, and selected a complete official ticket of candidates for the Institute offices that will become vacant August 1, 1928.

The committee consists of fifteen members, one selected by the executive committee of each of the ten Geographical Districts, and the remaining five elected by the Board of Directors from its own membership.

Those present were: George H. Ahlborn, Topeka, Kansas; C. C. Chesney, Pittsfield, Mass.; A. B. Cooper, Toronto, Ont.; H. C. Don Carlos, Toronto, Ont.; O. J. Ferguson, Lincoln, Neb.; John B. Fisken, Spokane, Wash.; H. W. Hitchcock, Los Angeles, Calif.; B. G. Jamieson, Chicago, Ill.; J. E. Kearns, Chicago, Ill.; H. A. Kidder, New York, N. Y.; G. L. Knight, Brooklyn, N. Y.; H. P. Liversidge, Philadelphia, Pa.; L. W. W. Morrow, New York, N. Y.; Arthur G. Pierce, Cleveland, Ohio; W. S. Rodman, University, Va.; and National Secretary F. L. Hutchinson. Mr. C. C. Chesney was unanimously elected chairman of the committee.

The following is a list of the official candidates:

FOR PRESIDENT

R. F. Schuchardt, Electrical Engineer, Commonwealth Edison Company, Chicago, Ill.

FOR VICE-PRESIDENTS

North Eastern District: E. B. Merriam, Engineer, Switchboard Department, General Electric Company, Schenectady, N. Y.

New York City District: H. A. Kidder, Superintendent of Motive Power, Interborough Rapid Transit Company, New York, N. Y.

Great Lakes District: W. T. Ryan, Professor, Electric Power Engineering, University of Minnesota, Minneapolis, Minn.

South West District: B. D. Hull, Engineer, Southwestern Bell Telephone Company, Dallas, Texas.

North West District: G. E. Quinan, Chief Electrical Engineer, Puget Sound Power & Light Company, Seattle, Wash.

FOR MANAGERS

A. E. Bettis, Vice-President, Kansas City Power & Light Company, Kansas City, Mo.

J. Allen Johnson, Electrical Engineer, Niagara Falls Power Company, Niagara Falls, N. Y.

A. M. MacCutcheon, Engineering Vice-President, Reliance Electric & Engineering Company, Cleveland, Ohio.

FOR TREASURER

George A. Hamilton, Elizabeth, N. J. (re-nominated).

The Constitution and By-Laws of the Institute provide that the nominations made by the National Nominating Committee shall be published in the January issue of the Institute JOURNAL, and provision is made for independent nominations as indicated below:

CONSTITUTION

SEC. 31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the National Secretary when and as provided in the By-Laws; such petitions for the nomination of Vice-Presidents shall be signed only by members within the District concerned.

BY-LAWS

SEC. 22. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with Article VI, Section 31 (Constitution), must be received by the Secretary of the National Nominating Committee not later than February 15 of each year, to be placed before that Committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the National Nominating Committee in accordance with Article VI of the Constitution and sent by the National Secretary to all qualified voters during the first week in March of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

National Nominating Committee
By F. L. HUTCHINSON,
Secretary

Biographical Sketches of Candidates

FOR PRESIDENT

R. F. Schuchardt

Rudolph Frederick Schuchardt was born in Milwaukee, Wisconsin, December 14, 1875, and received his early education in private and public schools in that city. He was graduated from the University of Wisconsin with the degree of B. S. in Electrical Engineering in June, 1897, and was awarded the degree of E. E. in 1911.

During the first year after his graduation, he was employed by the Janesville (Wis.) Electric Light and Power Company as general utility man, and later by Meysenburg and Badt, Chicago, as engineering salesman. Since July 1, 1898, he has been with the Chicago Edison Company and its successor, the Commonwealth Edison Company. He was in the Testing Department from November 1899 to November 1906, passing through all stages from an assistant to the acting head, which position he held for 14 months. In November 1906, Mr. Schuchardt was appointed Engineer of Electrical Construction, and in 1909 he was appointed Electrical Engineer of the company, which position he still holds.

While acting head of the Testing Department, he had responsible charge of and personally directed all engineering and acceptance tests on all station and substation equipment installed. In the position which he now holds, he is in charge of all electrical construction in stations and substations, and has done important special work on the complete scheme of system protection.

He is the author of a booklet entitled "Panama and the Isthmian Canal," and a number of technical papers on such subjects as meters, transformer testing, rotary converter substations, and the protection of high voltage transmission systems.

Mr. Schuchardt was elected an Associate of the Institute in 1903, and was advanced to the grade of Member in 1909 and to the grade of Fellow in 1912. He was a Vice-President of the Institute for the years 1922-1924. His committee activities in the Institute have been as follows: chairman of Power Generation Committee 1921-22; and member at various times of the Education, Power Generation, Protective Devices, Standards, Power Transmission and Distribution, Meetings and Papers, Executive, Electrical Machinery, and Law Committees. He is still a member of the Law Committee.

His other society memberships include Institution of Electrical Engineers (Great Britain), Western Society of Engineers, Illuminating Engineering Society, National Electric Light Association, Society of American Military Engineers, and American Academy of Political and Social Science. He is also a member of Tau Beta Pi.

FOR VICE-PRESIDENTS

E. B. Merriam

Ezra Bassett Merriam is Engineer of the Switchboard Department of the General Electric Company. He was born May 21, 1880, in New Haven, Conneticut.

He entered the student engineers department of the General Electric Company in 1900. After leaving this department, Mr. Merriam had charge of outside testing for the Switchboard Department. Later he was connected with the designing department, having to his credit many patents on circuit interrupting and switchboard devices, and considerable pioneering work in outdoor switching stations.

Leaving the Switchboard Department as Assistant Engineer, in 1917 he was appointed Director of Industrial Relations of the Schenectady Works of the General Electric Company, and in 1922, leaving the factory work, was appointed Executive Engineer of the Switchboard Department, this department having plants in Baltimore, Philadelphia, and Schenectady. In June, 1927, he was appointed Engineer of the Switchboard Department, which position he now occupies.

Mr. Merriam joined the Institute in 1906, and was transferred to the grade of Member in 1923. He has done much useful work for the Institute and is now a Director. He was chairman of the Schenectady Section in 1911-12. and during recent years has served as a member of the Education, Protective Devices, Applications to Marine Work, and Law Committees. He is at present a member of the last two of these committees as well as the Committee on Iustruments and Measurements, and is Chairman of the Membership Committee.

H. A. Kidder

Harry Alvin Kidder is Superintendent of Motive Power of the Interborough Rapid Transit Company of New York City. He was born in Cambridge, Massachusetts, March 24, 1874. After having operated for several years a number of small steam plants in New York City, he entered the Testing Department of the General Electric Company in 1903. He was later employed as an engineer in the Railway Motor Department of that Company, remaining there until 1906 when he went with the Interborough Rapid Transit Company as Assistant Electrical Superintendent. Appointed Electrical Superintendent in 1914, and Assistant Superintendent of Motive Power in 1920, he became Superintendent of Motive Power in 1921.

He was elected an Associate of the Institute in 1906, was transferred to the grade of Member in 1921, and has served the Institute in many capacities, including membership in the following committees: Power Generation, Headquarters, Standards, Executive, Finance, Coordination of Institute Activities, Edison Medal, Transportation, U. S. National

Committee, I. E. C., and Special Committees on Institute Prizes, Technical Activities, and Contacts with the Public. At present he is a member of the first nine committees named and Chairman of the Finance Committee. He has been a Director since 1925, and was Chairman of the New York Section during the year 1925-26. He has been Chairman of the Winter Convention Committee and has served as a member of that Committee several times.

Mr. Kidder is a Past-President of the New York Electrical Society, a Trustee of the United Engineering Society, and a member of the Assembly of the American Engineering Council. He is also a member of the American Electric Railway Association.

W. T. Ryan

William T. Ryan, E. E., Professor of Electric Power Engineering at the University of Minnesota, and Consulting Electrical Engineer, was born at Joice, Iowa, February 28, 1882. He is a graduate of the University of Minnesota.

His first years after graduation were spent with the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa. and at Salt Lake City, Utah. In 1907 he went to the University of Minnesota as Instructor in Electrical Engineering. Since 1923 he has been Professor of Electric Power Engineering. Since 1921 he has also supervised the valuation of public utility properties for the Minnesota Tax Commission. He has done considerable consulting work in Minnesota and South Dakota during the last 15 years.

His published writings include three books and about 40 magazine articles.

Professor Ryan joined the Institute in 1907, and was transferred to the grade of Member in 1912. He has twice been Chairman of the Minnesota Section, and now represents that Section on the Board of Directors of the Minnesota Federation of Architectural and Engineering Societies. In 1923 he was President of The Engineers' Club of Minneapolis and in 1924 was President of the Minnesota Federation of Architectural and Engineering Societies. As President of the Engineers' Club of Minneapolis and later as President of the Minnesota Federation, he fostered very effectively the idea of engineers taking a much greater part in civic and public affairs by giving their service to and cooperating with the various civic bodies, and City and State departments.

His other memberships include Sigma Xi, Tau Beta Pi, Eta Kappa Nu, Society for the Promotion of Engineering Education, and National Electric Light Association. He is also a member of a number of local organizations and several important committees.

B. D. Hull

Blake D. Hull was born at Galesburg, Michigan, September 12, 1882. Soon thereafter, his parents moved to Delphos, Kansas, at which point he received his grade and high school education. He entered the University of Kansas in 1900, taking some special courses in economics and civil engineering, finishing in 1905 with a Bachelor of Science degree in electrical engineering.

In July of 1905, he entered the Engineering Department of the Bell Telephone Company at Kansas City, and has been with that Company in engineering work of various kinds since that date.

In 1912 he was transferred to the general staff at St. Louis and in 1926 to Dallas, Texas, where he is now in charge of all engineering work for the Bell properties in the State of Texas.

In local Institute work he has taken a productive part. He became an Associate in 1915 and a Member in 1926. While serving as chairman of the St. Louis Section in 1924-25, he was made chairman of the Spring Convention held in that city in 1925, and directed a very successful meeting.

His other memberships include the Institute of Radio Engineers and local organizations.

George E. Quinan

George E. Quinan, Chief Electrical Engineer, Puget Sound Power and Light Company, Seattle, Washington, was born in Chicago in 1878. After graduating from the University of California in 1903, he was employed by the Washington Water Power Company on construction work, later doing similar work for the Tacoma Railway and Power Company. In 1907 he became Assistant Superintendent of that company. In 1911 he was made Operating Superintendent of the then Seattle Electric Co., later the Puget Sound Traction, Light, and Power Company, and in 1915 was engineer in charge of electrical and mechanical engineering in the Seattle District, finally reaching his present position of Chief Electrical Engineer. Mr. Quinan joined the Institute in 1918 and was transferred to the grade of Fellow in the same year. He has served on the Safety Codes and the Membership Committees. During the administrative year 1919-20 he was Chairman of the Seattle Section.

FOR MANAGERS

A. E. Bettis

Alexander E. Bettis was born at Kansas City, Missouri, December 16, 1885. After graduating from a manual training high school, he was a student in the electrical and structural engineering courses of a local night school for four years.

He has been employed by the Kansas City Power and Light Company and its predecessor, the Kansas City Electric Light Company, since 1905, having held responsible and supervisory positions in the Construction, Engineering, Designing and Operating Departments. In 1916 he became General Superintendent, and in 1924 was elected a Vice-President of the Company and placed in charge of engineering, construction, and operation, which position he still holds.

Mr. Bettis supervised extensive changes in the distribution system of the Kansas City Power and Light Company and the development and application of automatic substations for supplying power to street railways.

He joined the Institute in 1922, and was transferred to the grade of Member in 1924 and to the grade of Fellow in 1926. He has been a Vice-President since 1926.

J. Allen Johnson

Joseph Allen Johnson was born at Northboro, Massachusetts, June 21, 1882, and received his early education in the schools of that town. He was graduated from the Worcester Polytechnic Institute with the degree of B. S. in Electrical Engineering in 1905.

From 1905 to 1912, he was employed as junior engineer in electrical engineering work by the Ontario Power Company of Niagara Falls. He was appointed Electrical Engineer of this Company in 1912 and placed in charge of all electrical design and engineering. In 1917 he was appointed Assistant Engineer of the Hydroelectric Power Commission of Ontario, but still retained his other position, and in 1918 he was appointed Electrical Engineer of the Cliff Electrical Distributing Company and Hydraulic Power Company of Niagara Falls, N. Y., and placed in charge of electrical design and new projects. With the consolidation of these companies and the Niagara Falls Power Company to form the Niagara Falls Power Company in 1918, he became Electrical Engineer in charge of all electrical design and engineering.

Mr. Johnson has contributed a number of important technical papers on such subjects as excitation and voltage control, reactors in hydroelectric stations, fire protection in a-c. generators, retardation method of loss determination, etc. He was awarded the Best Paper Prize, District No. 1, 1926, for his paper entitled "The Retardation Method of Loss Determination as Applied to the Large Niagara Generators."

He joined the Institute in 1907, and was transferred to the grade of Fellow in December 1927. He has served as a member of the Electrochemistry and Electrometallury, Electrical Ma-

chinery, and Protective Devices Committees, being still a member of the latter and chairman of its subcommittee on Lightning Arresters. He was the organizer and first chairman of the Niagara Frontier Section and served in that capacity from the date of its organization, February 10, 1925, to July 31, 1926.

He is also a member of the National Electric Light Association and the American Electrochemical Society.

A. M. MacCutcheon

Alexander M. MacCutcheon, Engineering Vice-President of the Reliance Electric and Engineering Company of Cleveland, Ohio, was born at Stockport, New York, December 31, 1881. He was graduated from the Albany State Normal College in 1901, and taught mathematics and science in high schools until 1904, when he entered Columbia University. He was graduated in electrical engineering in 1908.

While employed by the Crocker-Wheeler Company, 1909-1914, he was successively in charge of engineering estimates, all estimates and proposals, and the drafting room, and also spent several months on alternator design. In 1914, he took charge of all new design work for the Reliance Electric and Engineering Company. He was appointed Chief Engineer in 1917, and in the fall of that year entered the U. S. Navy. At the time of his release in 1919, he was Lieutenant in charge of fire control on the U. S. S. *Louisiana*. After returning to his former position early in 1919, he was elected a Director of the Company in 1920, and appointed Vice-President in charge of Engineering in 1923.

Mr. MacCutcheon joined the Institute in 1912, and was transferred to the grade of Member in 1915 and to the grade of Fellow in 1926. His committee activities in the Institute include the following: Chairman of Committee on General Power Applications; member at various times of General Power Applications, Standards, Electrical Machinery, and Membership Committees; present member of all these except Membership; and present Chairman of the Direct Current Motors and Generators Subcommittee of the Electrical Machinery Committee. He was a member of the 1916 Annual Convention Committee, has been chairman of several committees of the Cleveland Section, and was Chairman of the Section in 1920-21.

For a number of years Mr. MacCutcheon has been active in the work of the Association of Iron and Steel Electrical Engineers, and has delivered 13 papers before this Association.

FOR TREASURER

George A. Hamilton

Mr. Hamilton, a charter member of the Institute and its first Vice-President, 1884-86, has served as National Treasurer since 1895. A biographical sketch was published on page 1306 of the December, 1927, issue of the JOURNAL.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 16, 1927.

There were present: President B. Gherardi, New York; Vice-Presidents H. M. Hobart, Schenectady, B. G. Jamieson, Chicago, G. L. Knight, Brooklyn, N. Y., O. J. Ferguson, Lincoln, Neb., J. L. Beaver, Bethlehem, Pa., A. B. Cooper, Toronto; Managers J. B. Whitehead, Baltimore, M. M. Fowler, Chicago, H. A. Kidder, New York, I. E. Moultrop, Boston, H. C. Don Carlos, Toronto, F. J. Chesterman, Pittsburgh, F. C. Hanker, Sharon, Pa., E. B. Meyer, Newark, N. J.; National Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting of October 19, 1927, were approved.

Actions taken at meetings of the Board of Examiners held November 2 and December 14, 1927, were approved. Upon the recommendation of the Board of Examiners the following actions were taken: 540 Students were ordered enrolled; 90 applicants were elected to the grade of Associate; 7 applicants were elected to the grade of Member; 1 applicant was reinstated to the grade of Fellow.

The Board ratified the approval by the Finance Committee for payment, of monthly bills amounting to $46,203.

In accordance with Section 22 of the Constitution, the following were made "Members for Life" by exemption from future payment of dues: Paul T. Brady, Reginald Gordon, W. M. Morday, and M. T. O'Dea.

Suggestions adopted at the conference of Section Delegates held during the Summer Convention, in June 1927, were considered; and upon the recommendation of the Committee on Coordination of Institute Activities, the following actions were taken:

1. That Sections be encouraged to enroll local members, not limited to engineers, but to include any persons interested in the application of engineering to the advancement of the public welfare—with the provision that it be understood that while we would urge that any one in the local membership who is eligible should be encouraged to join the Institute, nevertheless, it was not the primary purpose in forming local membership to afford a classification for those who are eligible for the society, but rather for the general public who are not eligible.
2. That approval be given to the suggestion that each District Executive Committee develop a plan whereby each Section in the District shall be assisted in securing one or more prominent speakers each year, with the understanding that the District Executive Committee will have the constant encouragement and cooperation of Headquarters.
3. To approve the recommendation that Section programs and portions of national and regional meetings that are of interest to the general public and which will contribute to a better public appreciation of the services rendered by the engineering profession, be broadcast, whenever practicable.
4. That the Sections Committee be charged with the responsibility of putting these plans into effect, with the cooperation of the Committee on Coordination of Institute Activities.

Approval was given to the dates, May 9-11, 1928, for the New Haven (Conn.) Regional Meeting.

Upon the recommendation of the Finance and Sections Committees, authorization was given for the extension of territory of the San Francisco Sections to include the counties of Merced, Madera, Monterey, San Benito, and Fresno, as requested by the Section and by the members in those counties.

The publication Committee presented a recommended policy covering Institute publications, drawn up after consideration of the comments that had been received regarding proposed changes in policy which had been published in the November JOURNAL. The Board adopted the recommended policy, which is printed elsewhere in this issue.

The following amendments to the by-laws were adopted:

Section 14.—

The following sentence added:

"A resignation received after June first but prior to the expiration of the first quarter of the fiscal year, shall involve payment of only the dues for that quarter, this consideration to be extended to non-resident members until November first."

Section 25.—

Old Section cancelled and the following substituted:

"There shall be three national conventions of the Institute each year, namely, the Winter Convention, the Summer Convention, and the Pacific Coast Convention, with such other additional national meetings as may be authorized from time to time by the Board of Directors, the location and dates of all national meetings to be determined by the Board of Directors."

Section 31A.—

Section added as follows:

"To facilitate cooperation among the Student Branches there shall be a Committee on Student Activities in each Geographical District, consisting of the Vice-President, District Secretary, and the Counselors of all Branches within the District. The Committee shall elect one of the Counselors as its Chairman, and may elect such other officers as it deems desirable."

Section 46.—

Section changed to read as follows:

"The expenditures for transportation of Section delegates, as referred to in the Constitution, and for all other Committees or activities for which a similar appropriation shall

be provided by the Board of Directors, shall be paid from the Institute treasury at the rate of ten cents (10c.) per mile, one way, from the place of residence to the meeting place."

Section 47.—

The word "Summer" substituted for the word "Annual" in the first sentence.

Sections 64 and 97.—

"TRANSACTIONS" substituted for "annual TRANSACTIONS."

Section 77.—and various other Sections.

Wherever a reference is made to "Annual Convention," the word "Annual" cancelled and the word "Summer" substituted.

Section 95.—

The first sentence of this Section changed to read as follows:

"The National Secretary is authorized to receive annual subscriptions to the monthly JOURNAL at the rate of $10.00 per annum with an extra postage charge sufficient to cover the mailing cost to all countries to which the bulk rate of postage does not apply."

In accordance with the recommendations of the Standards committee, the following actions were taken.

(1) Approved report dated August 1, 1927, of Sectional Committee on Insulated Wires and Cables for submission to the A. E. S. C.

(2) Approved Standards for Industrial Control Apparatus as revised by the Sectional Committee on Standards for Industrial Control Apparatus, in April 1927.

(3) Approved report, dated June 22, 1927, of the Sectional Committee on Rating of Electrical Machinery on the revision of the rating paragraphs of Standards Nos. 5 and 7.

Approved recommendation that the Sectional Committee on Rating of Electrical Machinery be discharged if and when the material covered by its report (the rating sections of Standards Nos. 5, 7, and 9) has been approved by the A. E. S. C. as American Standard.

(4) Approved revisions of Standard No. 7 made by the Sectional Committee on Rating of Electrical Machinery and the Sectional Committee on Alternators, Synchronous Motors, and Synchronous Machines in General.

The Board voted sponsorial approval of certain editorial revisions of the report on Mathematical Symbols, prepared by the Sectional Committee on Scientific and Engineering Symbols and Abbreviations, and previously approved by the Board for submission to the American Engineering Standards Committee.

Approval was given to the admission of the Cast Iron Pipe Research Association to membership in the American Engineering Standards Committee.

Upon the request of the Research Committee, the following resolution was adopted:

WHEREAS, Engineering Foundation in its desire to encourage and promote experimental research in the fields of engineering, has expressed willingness to consider applications from individuals for financial assistance in such work, and

WHEREAS, Engineering Foundation has asked that the experimental problems in view first be submitted to one of the Founder Societies for the endorsement of its importance, and

WHEREAS, Professor John B. Whitehead of the Johns Hopkins University, as chairman of the Committee on Electrical Insulation, Division of Engineering and Industrial Research, National Research Council, has made an extended study of our present knowledge of dielectric behavior and of electrical insulation, and is now conducting a research in this field, under a grant from Engineering Foundation, and has made substantial progress therein, therefore be it

RESOLVED: That the American Institute of Electrical Engineers regards the phenomenon of dielectric absorption as of great importance in its bearing on the properties of electric insulation, and endorses it as a promising problem for experimental attack; and be it further

RESOLVED: That the Institute requests the Foundation to make an appropriation and to continue its financial support of the research in this field now being conducted bv Professor Whitehead, Fellow A. I. E. E., and under the auspices of the Research Committee of this Institute.

Mr. Edward D. Adams was reappointed a representative of the Institute on the Library Board of the United Engineering Society for the four-year term commencing January 1, 1928.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

Edison Medal Awarded to William D. Coolidge

The Edison Medal has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to Dr. William D. Coolidge, "for his contributions to the incandescent electric lighting and the X-ray arts."

The Edison Medal was founded by associates and friends of Mr. Thomas A. Edison, and is awarded annually for "meritorius achievement in electrical science, electrical engineering, or the electrical arts." by a committee consisting of twenty-four members of the American Institute of Electrical Engineers.

The following engineers and scientists have been recipients of the medal: Elihu Thomson, Frank J. Sprague, George Westinghouse, William Stanley, Charles F. Brush. Alexander Graham Bell, Nikola Tesla, John J. Carty, Benjamin G. Lamme, W. L. R. Emmet, Michael I. Pupin, Cummings C. Chesney, Robert A. Millikan, John W. Lieb, John White Howell, and Harris J. Ryan.

WILLIAM DAVID COOLIDGE

William David Coolidge, assistant director of the research laboratory of the General Electric Company, and physical chemist, was born at Hudson, Massachusetts, October 23, 1873, the son of Albert Edward and M. Alice Coolidge. Dr. Coolidge is a graduate of the Massachusetts Institute of Technology, B. S., 1896, and of the University of Leipzig, Ph. D., 1899. He has been assistant in Physics, instructor in Physical Chemistry and assistant professor of Physico-chemical Research of the Massachusetts Institute of Technology. Dr. Coolidge became associated with the General Electric Company in 1905 and was made assistant director of the research laboratory in 1908. He was awarded the Rumford Medal, 1914; Howard N. Potts Medal, 1926; Louis Edward Levy Medal, 1926; Hughes Medal, (Royal Society, London) 1927. Dr. Coolidge is a member of the American Association for the Advancement of Science; American Chemical Society; American Electrochemical Society; American Physical Society; American Institute of Electrical Engineers; American Academy of Arts and Sciences; Washington Academy of Sciences. He is an honorary member of the American

Roentgen Ray Society; American Radium Society; Radiological Society of North America; Roentgen Society (of England); Societe de Radiologie Medicale (of France) and Nordick Forening for Medicinsk Radiologi.

Washington Award Presentation February 2, 1928, Chicago

The Washington Award, an honor "to be annually presented to an engineer whose work in some special instance or whose services in general have been noteworthy for their merit in promoting public good," is administered by a committee composed of representatives of the Western Society of Engineers, through which it was founded, and the four national engineering societies.

The Award for the year 1928 is to be conferred upon Doctor Michael I. Pupin, Past President of the Institute. The presentation will be made at a joint meeting of the five societies interested to be held in the Palmer House, Chicago, at dinner on the evening of February 2.

Doctor Max Mason, President of the University of Chicago and a fellow scientist, will make an address on "Pupin, the Scientist." President Gherardi will speak of the commercial application of Pupin's work and the presidents of the other societies are expected to touch upon his contributions to the advancemet of human progress from the angle of the engineer and the layman.

It is expected that a very large number will attend this unique meeting as the members of all five societies are, of course, invited. Because of Dr. Pupin's place in the Institute, none of its members living in or near Chicago will wish to miss this interesting occasion.

Regional Meeting in St. Louis

The second regional meeting of the Southwest District of the Institute will be held in St. Louis, Mo., on March 7, 8 and 9. Arrangements are going forward for the meeting and details of the program will be announced in the February issue of the Journal. The general committee in charge is as follows: Chairman, A. E. Bettis, Vice-President in 7th District A. I. E. E.; Vice-Chairman, L. F. Woolston; Secretary, Henry Nixon; A. E. Allen, R. L. Baldwin, Chris Kraft, H. E. McDowell, W. H. Millan, G. H. Quermann, L. P. VanHouten and P. M. Weinbach.

AMERICAN ENGINEERING COUNCIL

THE ANNUAL MEETING

The Annual Meeting of the Assembly of American Engineering Council will be held in Washington, D. C., January 10, 1928. The Administrative Board for 1927 will hold its last meeting the afternoon of January 9th. The Mayflower Hotel will be the headquarters for the Meeting. The Annual Dinner of the Council will be held on the evening of January 10th. The honor guest and principal speaker this year will be Sir Esme Howard, Ambassador from Great Britain to the United States. Many other notables will be present. All meetings held under the auspices of American Engineering Council are open to the public, and especially are all members of member-organizations invited to attend.

SPECIAL WORK ON FLOOD CONTROL

To aid in solving the problem of flood control, the American Engineering Council will urge Congress to authorize an inventory of water resources of the United States under the direction of the Geological Survey, as announced by Dexter S. Kimball, Dean of Cornell University and President of the Council. It is believed that only by the assembling of complete data can safety to life and property be assured, and the question will be one of importance to be discussed at the coming annual meeting of the Council, January 10-11, 1928 at Washington, D. C.

Reorganization of the Department of the Interior to accomplish centralization under engineering supervision for large public works will be discussed and a program of action for 1928 adopted.

War Memorial to American Engineers

The Committee of engineering societies on the War Memorial to American Engineers has just announced that the clock and the carillon for the tower of the new Louvain Library will be made a memorial to *all* engineers of the United States who gave their lives in service for their country or its allies at home, overseas or on the seas, in any branch of service in the great war from 1914 to 1918. The Committee seeks information of all such men so that their names may be suitably recorded in this honor roll.

The Committee further announces that on the advice of its carillon architect, Mr. Frederick C. Mayer, who is also organist of the West Point Military Academy, the compass of the Louvain carillon has been increased from three to four octaves. It will thus have forty-eight bells and be at least the equal of the famous old carillon at Malines, Belgium, which for many years has been the finest in Europe,—indeed the finest anywhere in the Eastern Hemisphere, the standard of carillon excellence.

To assure the excellence of the musical quality of the Louvain bells and the mechanical perfection of the playing mechanisms, the Committee has awarded the contract for the clock and the carillon to Gillett & Johnston, of Croydon, England. This firm made the carillon for the Victory Tower of the Parliament Houses in Ottawa, at present the finest carillon in the Western Hemisphere, and the carillon in the Tower of the Graduate School of Princeton University. It is also producing the great carillon for the new Baptist church on Riverside Drive at 122nd Street, New York, being given by Mr. John D. Rockefeller, Jr. as a memorial to his mother. This carillon is to have more than a hundred bells and its largest bell, recently cast at Croydon, weighs 20 tons.

It is stated by the architect, Mr. Whitney Warren, of New York, that it is now expected that the Library building, the clock and the carillon will be ready for dedication July 4th, 1928.

The Louvain memorial continues to win approbation, without dissent. That it will be acceptable to our Belgian comrades is made beautifully clear by the following letter dated 22nd November 1927, from the Rector of the University of Louvain:

(Translation)

Official acceptance of War Memorial by University of Louvain.

Louvain, 22nd November 1927

To Mr. Edward Dean Adams, Chairman,
Committee of the Engineering Societies of New York.

Dear Mr. Adams:

It is with deep thankfulness that the academic authorities of the University of Louvain accept the gift which the American Societies of Civil Engineers, Mining Engineers, Mechanical Engineers and Electrical Engineers, will make to this University of a clock with four dials and a carillon of three octaves of thirty-six bells, to be placed in the tower of our new Library.

When we saw you plant on the 28th June in Heverle Park four seedlings of California redwood, we greeted with emotion, in those young trees, symbols of the interest borne by the engineering societies for our country and our Alma Mater. These trees will grow! In this again are they the symbol of the comradeship with which you honor us, since this comradeship, which was expressed at first by your presence at our celebration, has developed in five months to the point of manifestation by a truly royal gift.

Yes, may the bells of the carillon of Louvain soon sing, together with the glory of the American engineers who died on the field of honor during the great war, the generosity of the American engineers of 1927! That song will awaken for years to come the gratitude of the people of Louvain to those to whom they owe restoration from the disaster which they suffered in 1914, and, at the same time, they will remind and inspire themselves to imitate the examples of those American engineers who have carried their country to so great prosperity.

Condescend to accept, dear Mr. Adams, with the tribute of my deep gratitude, that of my highest respect.

P. LADEUZE,
Rector of the University

Midwest Power Conference, February 14-17

The third annual Midwest Power Conference will be held at the Hotel Stevens, Chicago, February 14 to 17. There will be sessions on many live topics and a number of the country's highest authorities will speak. The subjects include the following:

Power Accomplishments in Factory and Home.

The Relation of Power Development to Flood Control and Other River Problems.

Economics of Power Stations.

Fuel, Combustion, etc.

Electrical Transmission.

The annual banquet will be held on February 15 and inspection trips will be made on February 16.

All sessions will be open to interested engineers. Further information may be obtained from G. E. Pfisterer, Secretary, Midwest Power Conference, 930 Monadnock Building, Chicago, Ill.

ENGINEERING FOUNDATION

A TYPICAL LARGE-SCALE INVESTIGATION

The Engineering Foundation aims to undertake the class of researches that individuals, industrial organizations, colleges, and governmental bureaus are not likely to choose. Certain much-needed fundamental investigations can best be initiated or organized by such an institution as the Foundation. Great care is taken not to infringe on ground that can best be explored by spontaneous, individualistic effort.

An excellent example of the kind of large-scale research properly suited to the Foundation is the Arch Dam Investigation. This was taken up in response to requests from engineers in the far West. Among the agencies which cooperated in attacking this problem were the states of California and Oregon, the United States Bureau of Reclamation, the Bureau of Standards, the City of San Francisco, the County of Los Angeles, many power companies, four engineering colleges, engineers both in this and foreign countries, several bankers, and many manufacturers of equipment and materials. Ingenious tests are being made on a celluloid model of the Stevenson Creek Dam one-fortieth the size of the concrete dam. The results of these tests at Princeton University confirm remarkably the measurements on the large dam. Tests of large models of the Stevenson Creek Dam and of several other forms of arch dams are being undertaken in the laboratory of the University of Colorado at Boulder, under the patronage of the U. S. Bureau of Reclamation which has its principal engineering office at Denver.

No arch dam,—at least none built under engineering supervision—has been known to fail, although some have been built very thick and others surprisingly thin.

Although American engineers are famed for their faith in "figurability" of design, they tend to build unnecessarily heavy structures in order to be on the safe side.

Engineering needs just such stimuli to unify and arouse its cooperative spirit and to strengthen its bonds with the industries, the universities, the technical bureaus of government, and the endowed laboratories.

P. B. McDonald

Engineers Present Holland Tube Scroll

A ceremony of presentation of interest to all professional engineers of the country was held in New York Tuesday, December 13, at the Administration Building of the Holland Tunnel, the new traffic artery under the Hudson River from New York to New Jersey. The four National Engineering Societies were represented at this ceremony by Col. Willard T. Chevalier, member of the board of direction of the American Society of Civil Engineers and managing director of *Engineering News-Record.* On their behalf, he presented to the chairman of the New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission a beautifully engrossed, hand-illuminated parchment memorializing the achievements of Clifford M. Holland, the first Chief Engineer, and of Milton H. Freeman, his co-worker and successor, both of whom sacrificed their lives to the gigantic task. Ole Singstad, the present chief and an important factor in the designing and construction of the tunnel since its inception, was also included in the scroll. Col. Chevalier's speech of presentation was, in part, as follows:

"We are met today in behalf of the four National Engineering Societies, The American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers,—which, in turn, represent more than fifty-seven thousand professional engineers—and we come to express the appreciation of a profession for exceptional recognition extended by you to those of its members who have served you in the accomplishment of your unprecedented task:

Appreciating the tributes paid to the skill and devoted service of

CLIFFORD M. HOLLAND, MILTON H. FREEMAN
and OLE SINGSTAD

Chief Engineers of the Holland Vehicular Tunnel, and to their engineering assistants,

upon the occasion of the formal opening of the tunnel on November twelfth, nineteen hundred and twenty-seven, and especially appreciating the naming of the tunnel after Mr. Holland and the East Plaza after Mr. Freeman and Executive Officers of the Above named National Engineering Societies, in behalf of the membership of these societies, some fifty-seven thousand in number, hereby express in turn their appreciation to the members of

THE NEW YORK STATE BRIDGE AND TUNNEL COMMISSION
and
THE NEW JERSEY INTERSTATE BRIDGE AND TUNNEL COMMISSION

of the recognition accorded the engineering profession in this enterprise so significant in its technical phases and in its economic and social aspects.

Metric Standards Urged at Pacific Conference

Calling upon Congress to adopt the decimal metric weights and measures in the United States, the Pan-Pacific Standardization Conference met recently in San Francisco during the Pacific Trade and Travel Exposition. A series of round table discussions were held, at which reports were presented from Japan, Australia, Mexico and South America, indicating a worldwide trend to the metric units.

"It is manifest that the future trade of the Pacific is to be largely upon the metric basis," declared Calvert E. Hydes at the final session, "and it is urgent that the United States shall unify its commerce on these unvarying standards likewise. Already, the Philippines, Japan, Siberia, Indo-China, the Dutch Indies, Siam, French Oceania, Mexico, the Central American Republics, Colombia, Ecuador, Bolivia, Peru and Chile are among the Pacific countries on the metric basis. The Orient has definitely decided upon metric units and has rejected the so-called English units. China, for instance, is making rapid progress in adoption of the metric standards."

Endorsement was given to the Britten-Ladd Metric Standards Bill which will be introduced on the first day of the new Congress, providing for gradual establishment of metric measures in merchandising throughout the United States.

It was stated by speakers at the standardization conference that all civilized nations except the United States and the British Commonwealths are now using metric weights and measures, and that British units are largely different from those used in the United States. Metric standardization, it was prophesied, will soon be complete.

National Exposition of Power and Mechanical Engineering

The Sixth National Exposition of Power and Mechanical Engineering exceeded all expectations. As a record of progress, in diversity and interest of exhibits, as well as attendance, this exhibition far outstripped preceding events. During the week of December 5th through the 10th, the Grand Central Palace received over 110,000 visitors.

Annual Meeting of Civil Engineers

Many engineers are looking forward to the pleasure of attending the 1928 Annual Meeting of the American Society of Civil Engineers to be held January 18-20, 1928. The official program already sent in dicates the usual attractive featu res of these yearly gatherings.

The customary business meetings, reports, technical division meetings, luncheon, and smoker are on the program. Of special interest will be the award for the first time of the Hering Medal. For sentimental reasons this ceremony should have special significance.

The customary social events will provide the necessary interlude between the technical sessions. A special program has been prepared for the ladies.

Those who customarily enjoy the annual sessions need no urging to insure their presence.

McGraw-Hill Company Executives Confer With Institute Officers

Upon the invitation of Mr. James H. McGraw, President of the McGraw-Hill Publishing Company, the officers and Directors of the Institute who attended the Directors' Meeting on Friday morning, December 16, were guests at a luncheon at the Engineers' Club on that day, followed by an inspection of the McGraw Company's large modern plant. The Institute officers who attended included President Gherardi; Vice-Presidents Ferguson, Hobart and Jamieson; Managers Don Carlos, Fowler, Hanker, Kidder, Meyer, Moultrop and Whitehead; and National Secretary Hutchinson; those present from the McGraw-Hill organization included many members of the executive and editorial departments.

Following the visit to the plant, including the printing, binding, type-setting and other departments necessary for the production of the numerous periodicals and other publications of the McGraw Company, the whole group with the addition of a considerable number of members of the editorial departments of the McGraw-Hill Company's various publications which include *The American Machinist*, *The Engineering News Record*, *The Engineering and Mining Journal*, *Power*, *The Electrical World*, *The Electrical West*, *The Electric Railway Journal*, and several others, held a conference. President McGraw, in outlining the object he had in mind in arranging for the event, said that as the general objects of both the McGraw Company and the Institute were identical; namely, the advancement of electrical and other industries and the maintenance of a high standard of engineering,—and as the two organizations had found many ways to cooperate actively in the past, he believed it desirable that each should keep fully informed of the activities, the organization and the methods of the other, with the object of possibly discovering still further opportunities for cooperation.

National Secretary Hutchinson outlined briefly the aims of the Institute, the national, district and local organizations, and the methods used in carrying on the various activites. President Gherardi spoke upon the future of the Institute and the electrical industry, stating that there was every reason to believe that the Institute would continue to grow at a rate commensurate with the growth of the industry, and therefore continue to be of increasing benefit not only to the individual members and the industry but to Society in general.

Vice-Presidents E. J. Mahren and Malcolm Muir, of the McGraw Company, presented an exceedingly interesting outline of some of the more important activities of their organization.

Dr. John B. Whitehead and Mr. Irving E. Moultrop expressed appreciation on behalf of the visitors for the courtesies extended. The afternoon was greatly enjoyed by all concerned and afforded an excellent opportunity for the representatives of each organization to become better acquainted with the personnel, and learn more about the activities, of the other.

New Highway Engineering Bureau

The opening of offices in the National Press Building, Washington, D. C., for a new Highway Engineering Bureau, offering a source of information on matters relating to highway, transportation and similar problems is announced by Doctor Charles Upham, president of the Advisory Board of the Road Builders. This bureau will also have facilities for carrying on work with foreign countries. The consulting staff will include men of extensive training, and the organization will assume complete direction of projects, including preliminary reports, engineering and construction.

Road Builders' Association Holds Exposition Meet

Approximately 30,0000 road builders will convene on January 9th at Cleveland, Ohio, to inspect the largest good roads machinery and equipment exposition since the invention of the automobile.

Road building representatives from every section of the American Continents will exchange views on the best methods of construction, maintenance and financing of highways. The exposition will cover more than 150,000 square feet of floor space, and is estimated to cost in excess of $5,000,000. There will be delegates from many foreign countries, including Mexico, Cuba, and a number of nations of South and Central America. At least 25 foreign countries will be represented at the sessions. Charles M. Upham, Managing Director of the American Road Builders' Association is in charge of the meeting. Charles M. Babcock, the organizations president, will preside.

PERSONAL MENTION

Oswald Dale, for the past six years in charge of development engineering, sales of varnished insulations and radio products for the Acme Wire Co., New Haven, Conn., has now been chosen vice-president of The Wheeler Insulated Wire Company, Bridgeport, Conn.

W. Nelson Smith, who about a year ago returned from Western Canada and has since assisted several prominent engineering firms on heavy traction products, has now joined the organization of E. L. Phillips & Company, New York, N. Y., with whom he will continue in public utility engineering.

Jos. C. Forsyth, supervising engineer of the Electrical Bureau of the New York Board of Fire Underwriters, at a luncheon held in his honor December 21, 1927, was presented with a gold watch by the New York Electrical League in recognition of 11 years of faithful service.

Vladimir Karapetoff, Professor of Electrical Engineering at Cornell University, upon the recommendation of the Committee on Science and the Arts, has been awarded the Elliott Cresson Gold Medal by the Board of Managers of The Franklin Institute, "in consideration of the inventive ability, skill in design and detailed theoretical knowledge of kinetics and electrical engineering displayed in the development of computing devices." Presentation will take place at the annual Medal Day meeting of the Franklin Institute, May 16, 1928.

I. F. BAKER, a veteran in the Westinghouse Company, having served them in various capacities both here and abroad, has been promoted to the office of manager of the Far Eastern Department of the Westinghouse International Company. He comes to his new position from Japan, where he has been managing director of the Westinghouse interests, president of the American Merchant's Association of Tokio and acting president of the American Association of Tokio. His new offices will be in New York.

L. W. BIRCH, of the Ohio Brass Company, Mansfield, has recently been made Assistant Manager of the Railway Sales Division. Mr. Birch graduated from the Ohio State University in 1917 and after a brief service in the army, in which he became First Lieutenant, joined the Carolina Power and Light Company and later the Pittsburgh Plate Glass Company. He became a member of the staff of the Ohio Brass Company in December 1921 and during recent years has specialized on the overhead distribution systems for electric railways. He is an Associate member of the American Institute of Electrical Engineers.

ROY WILKINS, who for the last six years has been assistant engineer of the Pacific Gas and Electric Company, on January 1 became a member of the Pacific Electric Manufacturing Company. Mr. Wilkins is probably best known for his accomplishments leading to the successful operation of 220,000-volt transmission lines, and consisting of research, design, tests and operation on such problems as corona, power transmission, relay application, circuit breakers, carrier-current telephony, hydraulic design, etc. After graduating from Kansas State Agricultural College with a degree of B. S. in E.E. in 1909 he joined the testing department of the General Electric Company, Schenectady, remaining there until 1912 when he went to the Pacific Gas and Electric Company as maintenance foreman. In 1917 and 1918 he served in the 37th Engineers, U. S. A. and returned to the Pacific Gas & Electric Company in 1919 as District foreman, later becoming Assistant Engineer in the Hydroelectric & Transmission Engineering Division. Mr. Wilkins joined the Institute as an Associate in 1916.

Obituary

Robert McAllister Lloyd, formerly prominent in the development of the storage battery and a member of the Institute since 1917, died December 15, in his 64th year. Mr. Lloyd, a native of Philadelphia, was educated at the Germantown Academy and Lehigh University. Immediately after his graduation, he entered the electrical field. He founded the Plante Company, which was later purchased by the Electric Storage Battery Company. In 1901, he established the Vehicle Equipment Company, which, after its organization, became the General Vehicle Company. Beside his consulting work, Mr. Lloyd was president, manager and director of Mantle & Company, engineers, and it was only recently that he organized the Sealed Containers Corporation. Mr. Lloyd was a member of the American Electro-Chemical Society and also of the Institute of Electrical Engineers of Great Britain.

B. C. Edgar, capitalist, vice-president and general manager of the Tennessee Electric Power Company and president of the Nashville Light and Power Company, died Dec. 25, at Chatanooga, Tenn. Mr. Edgar was born in Rahway, N. J., in 1878 and from his early boyhood became interested in the rapidly developing science of electricity. He graduated in electrical engineering from Rutgers in 1900, and was first employed by the Manhattan Railway in changing steamdriven trains to electrical operation. Later he was identified with the electrification of tunnels under the Hudson River. From 1909 to 1912 he was in California and the Pacific Northwest, with the Southern Pacific System, in electrifying suburban railway lines. For the next few years he was assistant general superintendent of the Columbus (Ohio) Railway, Light and Power Company. He was made general manager of the Nashville Company and the Chattanooga Railway and Light Company in 1914, and when these two companies merged with the Chatanooga and Tennessee River Power Company into the Tennessee Electric Power Company in June, 1922, he became vice president and general manager of the entire system. Mr. Edgar joined the Institute in 1911.

W. C. Chappell, for many years active in the electrical field, died late in November 1927, at Clover Leaf Canyon, Monrovia, California, after a long illness. He was born in London, England, November 11, 1886; his childhood was spent in South Africa. He was educated at home and at the Creiton Grammar School, near Exeter, Devonshire, later going to Zurich to study with a private tutor prior to entering the Zurich Polytechnikum. He entered the third year of a four year's course in Electrical Engineering at the Northampton Institute, Clerkenwell, London. This course consisted of six months college and six months workshop practise, which he took in the work shop of Messrs. Bruce, Peebles and Company's D-c. and A-c. Winding Department, Edinburgh. The sixth month, however, he went to Innsbruck, Austria, as electrical engineer to the Stubsi Valley Railroad. Mr. Chappell received some of his instructions on a-c. and d-c. machine design from Mr. H. M. Hobart of the General Electric Company. He was also in the Central Station Estimating Department of the Siemens Brothers Dynamo Works, Caxton House, London. But after 13 months, went to Vancouver, B. C., and entered the employ of the British Columbia Electric Railway as erecting engineer. Here he remained for three years, going thence to Philadelphia as the erecting engineer of the General Electric Company. His earlier experience in refrigerating engineering led him shortly after to connect with Messrs. Gay & Son. Los Angeles, Calif. as design engineer. He also served the Tasmanian Government Hydroelectric Department under a three years' engagement. Mr. Chappell joined the Institute in 1909.

Senter M. Jones, first vice-president, manager of purchases, and member of the executive committee of Century Electric Company, St. Louis, died very suddenly on December 11th, at the age of 47. Entering the organization in 1906, he always took keen interest in employee activities, and was highly esteemed by his associates. Besides being a member of the American Institute of Electrical Engineers, (1919), St. Louis Electrical Board of Trade, St. Louis Chamber of Commerce, and North Hills Country Club, he was a generous participant in civic and charitable organizations.

Past Section Meetings

SECTION MEETINGS

Boston

Unified Transportation for Boston, by W. S. Kelley, Consulting Engineer. November 8. Attendance 200.

Cincinnati

Theory of Lightning as Disclosed by Klydonograph Studies, by C. L. Fortescue, Westinghouse Elec. & Mfg. Co. Illustrated. November 10. Attendance 94.

Television, by Dr. G. W. King, American Tel. & Tel. Co. December 8. Attendance 148.

Cleveland

Automatic Train Control, by F. F. Fowle, of Frank F. Fowle & Co. The talk was preceded by a motion picture, entitled "The King of the Rails." November 17. Attendance 86.

Conneticut

The Changing Traffic of the Railroads, by D. M. Neiswanger, New York, New Haven and Hartford R. R. The meeting was preceded by an inspection trip to the Hartford Hump Yard. November 15. Attendance 60.

Electric Traffic Control Systems, by J. G. Regan, General Electric Co. Illustrated with slides. December 13. Attendance 30.

Denver

Television, by Dr. M. B. Long, Bell Telephone Laboratories, Inc. Illustrated with slides and motion pictures. A dinner preceded the meeting. November 18. Attendance 110.

Detroit-Ann Arbor

The Benefits of Interconnection, by C. W. Tippy, Consumers Power Company;

Engineering Features of the Transmission Line, by J. H. Foote, Commonwealth Power Corp., and

Substations at Ends of Transmission Lines, by S. M. Dean, Detroit Edison Co. November 16. Attendance 275.

Electrification, by H. L. Andrews, General Electric Co. Illustrated with slides. Joint meeting with Detroit Engineering Society. A dinner preceded the meeting. December 9. Attendance 150.

Erie

Inspection Tour of the International Electrotechnical Commission, by James Burke, Burke Electric Co., and

The Pyschology of Laughter, by C. M. Newcomb. November 15. Attendance 250.

Indianapolis-Lafayette

Modernizing Industrial Control Equipment, by W. B. Neeper, Allen-Bradley Co. Illustrated with slides. November 18. Attendance 47.

Ithaca

The Quest of the Unknown, by Prof. H. B. Smith, Worcester Polytechnic Institute. Illustrated. November 18. Attendance 80.

Lehigh Valley

The World Flight and Flying Illuminated, by Lt. Leigh Wade, Consulting Aviator. October 22. Attendance 67.

Russian Mining Problems, by J. H. Pierce of Stuart, James & Cooke, Inc. Illustrated.

Research, by L. A. Hawkins, General Electric Co. A dinner preceded the meeting. November 11. Attendance 97.

Recent Developments in Central Station Generating Plants, by N. E. Funk, Philadelphia Electric Co.; and

Mine Ventilation, by F. H. Nicholson, Lehigh & Wilkes-Barre Coal Co. Inspection trips to Wanamic Colliery and Hunlock Creek Plant of Luzerne County Gas & Electric Company was made prior to the meeting. December 3. Attendance 117.

Los Angeles

Movement of Overhead Conductors during Short Circuits, by Wm. S. Peterson, Bureau of Power & Light. Illustrated with slides. December 6. Attendance 146.

Louisville

Smoker. Discussion of the electrolysis situation in Louisville. October 25. Attendance 16.

Lynn

Chemistry, Manufacture, Classification and Uses of Bakelite, by L. B. Quigley, Bakelite Corp. Motion picture was shown, entitled "Manufacture of Bakelite." November 16. Attendance 80.

Dream Pictures, by Branson DeCou. Ladies' Night. November 21. Attendance 850.

Mexico

Annual Banquet. The following officers were elected: Chairman, B. Nikiforoff; Secretary, E. Luque. October 15. Attendance 40.

La Linea Internacional Telefonica New York-Mexico, by M. P. McCullough, Mexican Telephone Company. November 8. Attendance 40.

Milwaukee

Annual Meeting, Milwaukee Engineers' Society. Motion picture entitled "The Age of Speed," was shown. October 20. Attendance 40.

Hawaii, a Tropical Paradise, by Dr. S. A. Barrett, Milwaukee Public Museum. Illustrated with motion pictures and slides. November 16. Attendance 130.

Minnesota

Chicago District Electrical Developments, by B. G. Jamieson, Commonwealth Edison Co. A dinner preceded the meeting. October 24. Attendance 80.

Nebraska

Television, by Dr. M. B. Long, Bell Telephone Laboratory. Illustrated with slides and motion pictures. A dinner preceded the meeting. November 15. Attendance 280.

Niagara Frontier

Welland Ship Canal, by A. J. Grant, Engineer-in-Charge;

Niagara Power Development, by F. D. Corey, Niagara and Eastern Power Corp;

Proposed St. Lawrence Developments, by H. G. Acres, Consulting Engineer, and

The Peace Bridge, by E. P. Lupfer, Chief Engineer. A banquet preceded the meeting. The morning and afternoon were devoted to an inspection trip over the Canal. Joint meeting with Toronto Section, A. I. E. E.; Niagara, Hamilton and Toronto Branches, Engineering Institute of Canada; Toronto Branch, A. S. M. E., and Engineering Society of Buffalo. October 28. Attendance 600.

Transatlantic Telephony, by Ralph Bown, of A. T. & T. Co., President, I. R. E. Illustrated with slides and motion pictures. November 17. Attendance 15.

Storage-Battery Engineering and Development, by C. W. Bell, Gould Storage Battery Co., and

Dry-Battery Development, by A. T. Hinckley, U. S. L. Battery Corp. December 2. Attendance 80.

Philadelphia

Automatic Train Control, by W. H. Reichard, General Railway Signal Co. Illustrated with slides. November 14. Attendance 150.

Pittsburgh

The Modern Oscillograph—the Analyst of the Unknown, by J. W. Legg, Westinghouse Elec. & Mfg. Co. Illustrated. Joint meeting with Electrical Section, Engineers Society of Western Pennsylvania. November 9. Attendance 265.

Pittsfield

Biological Research, by Dr. A. W. Bray, Rensselaer Polytechnic Institute. A dinner preceded the meeting. November 15. Attendance 100.

The Human Side of the French Foreign Legion, by Major Zanovi Pechkoff. A dinner preceded the meeting. December 6. Attendance 700.

Portland

Rural Electrification Experiments, by H. J. Garver, and

X-Frame Construction for Rural Lines, by D. S. Young. November 22. Attendance 75.

Providence

View of the English Engineering Industry, by J. R. Ratcliff, Kent Instrument Works of London. November 15. Attendance 75.

Rochester

Transatlantic Telephony, by Dr. Ralph Bown, of A. T. & T. Co., President, I. R. E. Luncheon preceded the meeting. Joint meeting with Rochester Engineering Society and I. R. E. November 18. Attendance 156.

St. Louis

Superpower Transmission, by Robert Treat, General Electric co. November 16. Attendance 64.

Saskatchewan

Faults on Distribution Systems Located by Radio, by W. R. Pottle, Radio Inspector, Dept. of Marine and Fisheries. November 25. Attendance 35.

Schenectady

Personal Observations in Soviet Russia, by H. H. Dewey, General Electric Co. November 16. Attendance 325.

Steam and Electric Locomotives, by A. H. Armstrong, General Electric Co. Illustrated with slides. December 2. Attendance 175.

Seattle

The Boeing Airplane Company and Its Products, by C. N. Montieth, Boeing Airplane Co. Illustrated with motion pictures and slides. An inspection trip through the factory preceded the meeting. November 15. Attendance 65.

Sharon

Development of Military Aviation, by Col. Harry Graham, U. S. Army Comdr., Wright Field. Illustrated with motion pictures and slides. November 8. Attendance 297.

Southern Virginia

Annual Fall Meeting, Affiliated Engineering Society Sections of Virginia. November 11-12. (Full account given on page 1466, December JOURNAL).

Spokane

Rhythmic Corrugations in Highways, by Prof. H. V. Carpenter, State College of Washington. Joint meeting with Spokane Section, A. S. C. E., and Inland Empire Section, A. S. M. E. November 25. Attendance 60.

Springfield

Manufacture of Electrical Porcelain by the Wet Process, by C. W. Roberts, Locke Insulator Co. Two motion pictures were shown—one illustrating the manufacture of Mazda lamps by automatic machinery, and the other a travel picture of the Canadian National Railroad through the vacation camps of the Canadian Rockies. November 21. Attendance 45.

Toledo

Engineering and Economic Factors in Promoting a Super-Power Mine-Mouth Generating Station, by A. W. Morgan, H. L. Doherty Co. November 18. Attendance 32.

Toronto

Joint Meeting. October 28. (See October 28 meeting Niagara Frontier Section).

Capacitors, by M. C. Lowe, Canadian General Electric Co. Illustrated with slides. November 11. Attendance 67.

Urbana

A Year at Cavendish Laboratory at Cambridge, England, by Dr. C. T. Knipp, University of Illinois. Illustrated. Joint meeting with Electrical Engineering Society. November 16. Attendance 46.

Mathematics and Qualitative Analysis in Engineering, by R. E. Doherty, General Electric Co. November 22. Attendance 146.

Vancouver

Oscillographs, by Dr. H. Vickers, University of British Columbia. Illustrated by slides and a demonstration of phase displacement and other phenomena with a two-element instrument. December 6. Attendance 56.

Washington

Commercial Aviation, by Maj. C. M. Young, Department of Commerce;

Radio Aids for Air Navigation, by Haraden Pratt, Bureau of Standards, and

The Earth-Inductor Compass, by Dr. P. R. Heyl, Bureau of Standards. Slides and motion pictures were shown. A dinner preceded the meeting. November 8. Attendance 175.

Worcester

Electrical Reproduction of Music, by Prof. H. H. Newell, Worcester Polytechnic Institute. It was voted to join the Affiliated Engineering Societies of Worcester. November 28. Attendance 150.

A. I. E. E. Student Activities

STUDENT CONVENTION AT REGIONAL MEETING OF GREAT LAKES DISTRICT

The first day of the Regional Meeting of the Great Lakes District, held at Chicago November 28-30, 1927, was devoted to a Student Convention consisting of a technical session during the morning, a District Conference on Student Activities in the afternoon, and a smoker in the evening. Extensive plans had been made for the morning and afternoon sessions under the leadership of Professor J. F. H. Douglas, Chairman of the District Committee on Student Activities, who presided at both meetings.

TECHNICAL SESSION

The technical session was opened by an address of welcome by Mr. B. G. Jamieson, Vice-President, Great Lakes District, in which he welcomed the students to the Regional Meeting not only as guests but also as substantial, contributing units. He mentioned briefly the benefits to be derived by students in the preparation and presentation of papers.

The following papers were presented by students:

Substation Protective Devices, L. F. Masonick, Lewis Institute.

Locating Faults in Telephone Cables, A. R. Sansone, Lewis Institute.

Measurement of Transverse Reaction in Synchronous Machines by Use of Synchronously Revolving Contactor, E. E. Lashway and E. T. Baldwin, Marquette University. (Presented by E. T. Baldwin).

The Student Engineer's Attitude Toward His Work, J. F. Payne, Rose Polytechnic Institute.

Errors in Current Transformers at Abnormal Loads, L. L. Carter, Purdue University.

A Method of Design for Reactors Where a D. C. Component is Present, J. P. Barton, University of Minnesota, '27.

Historical Development of the Direct-Current Motor, Joseph Horan, University of Notre Dame.

The Localization of Faults on Parkway Cable, John Sargent, University of Wisconsin.

Recent Developments in Commercial Radio Telegraph Transmitters for Marine Use, by T. J. Boerner, University of Wisconsin. (Presented by John Sargent).

An Electrical Method of Obtaining the Compression Indicator Card of a High-Speed Compressor, by M. E. Fiene, University of Minnesota.

Experiences with Motor Maintenance in Pulp and Paper Mills, C. P. Feldhausen, University of Wisconsin. (Presented by title only).

A Study of Flux Conditions in Armature Teeth, T. B. Holliday and C. W. Kronmiller, Purdue University. (Presented by T. B. Holliday).

The papers were well presented, and all available time was devoted to discussion in which a considerable number of students participated. About 200 students were present.

CONFERENCE ON STUDENT ACTIVITIES

Of the thirteen Branches in the Great Lakes District, nine were represented by their Counselors and Chairmen, and each of the remaining four was represented by either Counselor or Chairman, at the Conference on Student Activities held at 2:00 p. m.

The program of the conference was as follows:

Management of Electrical Shows, K. E. Hunt, Chairman, Michigan State College Branch. (Presented by Elmer Kirk).

Financing Branch Activities, J. R. Adriansen, Chairman, Marquette University Branch, (Presented by P. C. Neumann); Professor F. A. Rogers, Counselor, Lewis Institute Branch.

Branch Programs, G. C. Brown, Chairman, University of Minnesota Branch; Professor J. A. Caparo, Counselor, University of Notre Dame Branch.

Social Activities of Branches, L. J. Van Tuyl, Chairman, University of Michigan Branch; Professor D. P. Moreton, Counselor, Armour Institute of Technology Branch.

Ways and Means of Interesting Under Class Men in Branch Activities, Arthur Drompp, Chairman, Rose Polytechnic Institute Branch; Professor A. N. Topping, Counselor, Purdue University Branch.

The Problem of the Branches, Professor C. M. Jansky, Counselor, University of Wisconsin Branch.

General Discussion

The reports on Electrical Shows and Branch Finances were based upon the results of extensive surveys made by means of

questionnaires sent to Student Branches, and contained summaries of data on many aspects of these subjects.

Mr. G. C. Brown and Professor J. A. Caparo described briefly the types of meetings held by their Branches at the University of Minnesota and University of Notre Dame respectively. At the former, Branch meetings are not well attended if held more frequently than once a month. Inspection trips are very popular, but smokers are not well attended. At the latter, the meetings consist of four parts: business, presentation of papers by students, discussion, and social features with refreshments.

On the subject of social activities, Mr. Van Tuyl considered one of the most valuable results of Branch meetings the making of acquaintances among students and faculty members, and said an occasional social meeting such as a smoker promotes this function effectively. Professor Moreton reported that all juniors and seniors in electrical engineering at Armour Institute of Technology are enrolled Students of the Institute, and also emphasized the importance of smokers to promote mixing. His Branch has two annual smokers which are attended by many alumni who discuss with the students problems they have met since leaving school.

Mr. Drompp said freshmen and sophomores do not have the natural interest in things of a professional nature that seniors have, and mentioned some means of increasing their interest, such as balanced programs without too much deeply technical material, placing each student on a program at least once, encouragement of discussion, social meetings, and placing the Branch before the students as an active, going organization. Professor Topping emphasized the necessity of spontaneous activity within a Branch, and said the students must participate actively in the programs in order to receive the greatest benefit. He said the A. I. E. E. conventions only rarely have activities arising outside the Institute and that the students should furnish Branch programs rather than depend upon outside speakers.

Professor C. M. Jansky opened his report with a brief perspective of the origin and purposes of the Student Branches, and said leaders cannot be developed by the use of outside speakers. He mentioned the many activities open to university students and the renown which may be received in them, while officers of Branches receive little or no distinction. He made a plea for greater recognition for students who are leaders in Branch work and for those who participate in the programs and other activities.

Smoker

A student smoker was held on Monday evening to afford the students, Counselors, and others an opportunity to become better acquainted. Brief addresses were given by Vice-President B. G. Jamieson and Professor J. F. H. Douglas, Chairman of the District Committee on Student Activities. Several entertainment features were provided and a buffet luncheon was served. All those present thoroughly enjoyed the activities of the evening.

BRANCH MEETINGS

Municipal University of Akron

Business Meeting. December 2. Attendance 10.

Alabama Polytechnic Institute

Farm Electrical Equipment, by Mr. Hightower, student, and

Financing Engineering Projects, by Professor W. W. Hill, Counselor. November 10. Attendance 55.

Motion picture, entitled "Manufacture of Paper," was shown. A talk was also given by an alumnus on what each student could do to make Auburn a better school. November 17. Attendance 68.

University of Arkansas

Electricity and the Organic Chemist, by Dr. Wertheim;

Electrical Development in Eastern Europe, by Maurice Koenblact, and

Report on Laboratory Experiment, by Dick Ray, Secretary. November 17. Attendance 17.

Television in Europe, by Harold Leimer, student, and

Advantages of Transmission of Power by Cable, by J. P. White, student. December 1. Attendance 13.

Armour Institute of Technology

Motion picture, entitled "The Development of Power," was shown. November 4. Attendance 43.

Brooklyn Polytechnic Institute

The Interconnection of Large Power Systems for Allocation of Loads, by Mr. Brandler, student, and

Industrial Control of Motors, by I. C. Diefenderfer, General Electric Co. Refreshments were served. November 11. Attendance 66.

Bucknell University

Steam Railroad Electrification, by G. B. Timm, Westinghouse Elec. & Mfg. Co. Illustrated by slides.

The Future of Electrification of Railroads, by Prof. W. K. Rhodes, Counselor. He also spoke on plans for future meetings. Motion picture, entitled "Romance of Rails and Power," was also shown. November 7. Attendance 34.

The Theory of Indicating Instruments, by Mr. Coby, Weston Electrical Instrument Co. Illustrated with slides. December 7. Attendance 38.

University of California

How Signals May Travel from the Transmitter to the Receiver, by E. M. Sargent, Sargent Radio Co., and

The Fynn-Weichsel Motor, by N. C. Clark. November 2. Attendance 45.

Business Meeting. Nomination of officers for second semester. (The following officers were elected several days later: Chairman, J. F. Bertucci; Vice-Chairman, Robert Kirkland; Secretary, N. C. Clark; Treasurer, H. H. Daniels). November 16. Attendance 26.

The California Institute of Technology

Business Meeting. Discussion of plans for holding next meeting at offices of General Electric Co. December 7. Attendance 10.

Catholic University of America

Use of the Carrier Wave in Line Telephony, by L. B. Bogan, Chesapeake and Potomac Telephone Co. D. V. O'Leary, Treasurer, gave a recitation of "Casey at the Bat." Refreshments were served. November 15. Attendance 28.

Carnegie Institute of Technology

Short Wave Radio Transmission and the Value of Amateur Stations, by Richard Tener, student, and

The Desirability of Having Student Speakers, by Prof. B. C. Dennison, Counselor, and Prof. G. M. Porter. November 2. Attendance 23.

Clemson College

Conowingo Power Development, by A. A. Walsh;

Edison and the Incandescent Lamp, by L. B. Moore, and

Current Events, by W. P. West. November 10. Attendance 26.

Colorado Agricultural College

Electrical Generators, by R. J. Nelson, student. Discussion of a stunt for Homecoming Day. November 14. Attendance 14.

Business Meeting. November 28. Attendance 10.

University of Colorado

Television, by Dr. M. B. Long, Educational Director, Bell Telephone Laboratories, Inc. Illustrated with slides and motion pictures. November 17. Attendance 85.

Problems in Broadcasting, by R. H. Owen, KOA Broadcasting Station, Denver. November 30. Attendance 40.

Cooper Union

A Maximum Demand Meter, by Charles Coles, student, and

Summer Experiences with A. T. & T. Company, by John Meehan, student. November 10. Attendance 40.

University of Denver

X-Ray Crystal Analysis, by B. E. Cohn, Instructor in Physics. Dates for meetings for the year announced. November 22. Attendance 14.

Drexel Institute

Development of Hydraulic Turbines, by Wm. Kelly, I. P. Morris Co. Joint meeting with A. S. M. E. Chapter. December 6. Attendance 22.

Duke University

Natural Resources in the Carolinas, by Prof. W. J. Seeley, Counselor. November 21. Attendance 11.

Georgia School of Technology

The Power Limit of Transmission Lines, by H. G. Harvey, Westinghouse Elec. & Mfg. Co. A mechanical model used to illustrate talk. November 25. Attendance 90.

University of Idaho

100 Kw. Radio Tubes, by C. N. Teed, student. Illustrated by slides. Discussion of the coming "Engineers Day." November 21. Attendance 18.

State University of Iowa

Oscillographs and Their Uses, by D. D. MacDougal, and

Benefits Obtained from Electric Heat Treatment, by R. C. Mathis. November 16. Attendance 29.

The Edison Battery, by M. H. Jensen;

Materials for Switchboard Panels, by G. L. Pruhdon;

Solution of a Cubic Equation, by P. Rosmovsky, and

Electric Practise in Copper Mining, by O. T. Stueck. November 23. Attendance 29.

The Romance of Power, by C. M. Ripley, General Electric Co. Joint meeting with Student Chapters of the A. S. C. E. and A. S. M. E., sponsored by A. I. E. E. Branch. November 30. Attendance 162.

Packing, by Herman Sader, Garlock Packing Co. Joint meeting with the Student Chapter of the A. S. M. E. December 7. Attendance 39.

Kansas State College

Opportunities of the Graduates with Industrial Companies, by Prof. R. G. Kloeffler, Counselor. He also gave a list of Companies which employed the Kansas State men for the last three years. October 31. Attendance 102.

Difficulties in Long Line Power Transmission, by D. W. Grant;

A 100-Kw. Vacuum Tube, by A. L. Morgan. Illustrated.

Mr Summer's Work with the Commonwealth Edison Company, by Kennis Evans. A motion picture, entitled "Big Deeds," was also shown. November 7. Attendance 79.

University of Kansas

Mr. S. M. DeCamp, Chairman, Kansas City Section, A. I. E. E., took charge of the meeting and introduced the speakers. A. E. Bettis, Vice-President, District No. 7, spoke on the importance of the A. I. E. E. and the value of combined meetings with students. A. P. Denton, Electrical Engineer, Denton Engineering and Construction Co., spoke on the National Electrical Code. Dr. H. P. Cady, University of Kansas, demonstrated some of the properties of liquid air. November 1. Attendance 100.

University of Kentucky

Digest of an Article on "Light," by T. H. Doeman;

Digest of an Article on "Electricity in Aviation," by H. E. Goldstine, and

Technical Terms Often Misused, by Prof. W. E. Freeman, Counselor. November 9. Attendance 33.

Lafayette College

A talk on his trip to Europe dealing especially with electric lighting and transportation was given by Prof. M. King, Counselor. November 26. Attendance 19.

Lewis Institute

Chicago Engineering, by E. J. Kelley, Chief Engr., Sanitary District of Chicago, and President, South Park Board. November 18. Attendance 150.

Louisiana State University

Motion pictures on Power Transformers were shown. Discussion of plans for "Electrical Vaudeville." Henry Joyner was elected Secretary-Treasurer. November 29. Attendance 20.

University of Maine

Opportunities in Illumination, by Charles Howard, Central Maine Power Co. November 10. Attendance 14.

Mercury Arc Power Rectifiers, by E. W. Jones, Secretary. December 1. Attendance 20.

Marquette University

Power Distribution in Chicago, by H. E. Wulfing, Commonwealth Edison Co. Joint meeting with University of Wisconsin and School of Engineering of Milwaukee Branches. A dinner preceded the meeting. November 14. Attendance 94.

Report on Regional Meeting at Chicago, by P. C. Neumann, and

Oil Geer Company, by Herbert Hartman, alumnus. December 8. Attendance 32.

Massachusetts Institute of Technology

What Kind of an Engineering Job Can I Get, and How Do I Go About Getting It? by O. W. Eshbach, Personnel Dept., A. T. & T. Co. Illustrated with three reels of films. A free supper was served preceding the meeting. November 11. Attendance 406.

History, Organization, and Scope of Stone & Webster, Inc., by N. H. Daniels. Two reels of motion pictures of the Conowingo Project were shown. December 2. Attendance 408.

Michigan State College

The Development and Methods of Manufacture of the Modern Insulator, by Brent Mills, Lapp Insulator Co. Committees appointed for Electrical Show to be held January 30 to February 4, 1928. November 8. Attendance 70.

Inspection trip to Jackson, by the Senior Class, where two substations and the Laboratories of the Consumers Power Company were visited. Attended a banquet in the evening given by the Detroit-Ann Arbor Section of the A. I. E. E. November 16. Attendance 35.

University of Michigan

Some Interesting Things About Atoms, by Prof. Barker, of the Physics Dept. Illustrated. November 10. Attendance 28.

Engineering School of Milwaukee

Talk by H. E. Wulfing, Commonwealth Edison Co. (See November 14 meeting of Marquette University above). November 14.

Mississippi A. & M. College

The General Electric Company and Its Student Training Courses, by Robert Caruthers. Appointments of various committees announced by Chairman. November 7. Attendance 35.

Missouri School of Mines and Metallurgy

Radio Program and entertainment for the Freshmen. Program for the school year of 1927-1928 outlined. Refreshments served. September 22. Attendance 21.

University of Nebraska

Television, by Dr. M. B. Long, Educational Director, Bell Telephone Laboratories, Inc. Film showing first demonstration of the apparatus. Joint meeting with Sigma Xi. November 16. Attendance 185.

Newark College of Engineering

The Development of the Vitaphone and Movietone, by D. C. McGaillard, Installation Supt., Acoustic Dept., Electric Research Products, Inc. November 14. Attendance 54.

College of the City of New York

Motion picture in two reels, entitled "Through the Switchboard," was shown Talk, illustrated by slides, was also given on this subject by S. B. Williams, Bell Telephone Laboratories, Inc. After the meeting an inspection of the Audubon Exchange of the New York Telephone Company was made. November 17. Attendance 25.

Inspection trip to the Edgecombe Exchange of the New York Telephone Company. December 1. Attendance 12.

Inspection of the many interesting exhibits at the Power Show. December 5. Attendance 11.

Inspection trip to Long Distance Exchange of the A. T. & T. Co. December 8. Attendance 10.

New York University

Business Meeting. November 29.

Designing an Illumination System for One of the Seven Wonders of the World—the Virginia Natural Bridge, by W. A. Oglesby (N. Y. U. '23), Illumination Engr., Westinghouse Lamp Co. December 1. Attendance 15.

North Carolina State College

Power Development in North Carolina, by J. H. Paget, Supt. of Power, Carolina Power and Light Co. Banquet. November 15. Attendance 30.

Steam Plants and Their Accessories, by Prof. W. J. Dana. Illustrated. December 13. Attendance 15.

University of North Carolina

Sag and Stress Analysis of Transmission Lines, by T. B. Smiley, Instructor. November 17. Attendance 21.

Regeneration of Energy on Electric Locomotives, by W. L. Brooker, student. December 1. Attendance 20.

Northeastern University

Engineering the Production of Radio Receivers, by A. F. Murray, Wireless Specialty Apparatus Co. November 1. Attendance 90.

Three motion pictures were shown, entitled respectively, "More Power to You"; "Revelations"; and "Power Transformers." December 6. Attendance 95.

University of Notre Dame

Dr. J. A. Caparo, Counselor, gave a brief talk on the importance of membership in the Branch and the benefits derived from presenting papers. The following officers were elected: President, Charles Topping; Vice-President, Fred Weiss; Secretary, George Conner; Treasurer, Joseph Horan; Publicity Agent, Laurence Wingerter. October 14. Attendance 87.

History of the Development of Direct-Current Motors, by Joseph Horan, student. Discussion of the desirability of attending the Regional Meeting in Chicago. Refreshments were served. November 14. Attendance 58.

Ohio University

November 9. Attendance 12.

Business Meeting. November 30. Attendance 13.

Ohio Northern University

How I Became Interested in Electrical Engineering, by B. Wyandt, and

The Electrification of the Truscon Steel Company Fabricating Plant. December 8. Attendance 20.

Ohio State University

Modern Application of Science, by Prof. A. W. Smith, Dept. of Physics. Programs for the meetings of the year 1927-28 were distributed. The possibility of holding a convention of Branches at Ohio State in the Spring was discussed. Dinner in Ohio Union. November 10. Attendance 68.

Oklahoma A. & M. College

Life of Edison, by G. E. Larazon. Motion picture, in three reels, entitled "The Benefactor" was shown. November 10. Attendance 55.

Being a Member of A. I. E. E. Society, by Benny Fouts, President. Motion picture in two reels, entitled "Wizardry of Wireless," was shown. December 7. Attendance 30.

University of Oklahoma

Some slides of a 50,000-Kv-a. Synchronous Condenser, a 91,500-Kw. Turbine and a 100-Kw. Transmitting Tube were shown, illustrating lectures given on same. November 17. Attendance 25.

Oregon State College

A. C. Vacuum Tubes, by J. C. Garman, Instructor in Physics. Illustrated by slides. Frank Blount was elected Publicity Manager. December 7. Attendance 45.

Pennsylvania State College

Conowingo Hydroelectric Installation.
Preparations and General Conditions, by W. C. Kirk;
Construction of the Dam, by J. F. Houldin; and
The Completed Dam, by H. E. Burcher. November 16. Attendance 47.

Inspection trip to air mail field, remote control radio station of air field, Milesburg Power Plant, Bellefonte Outdoor Substation, and Bell Telephone Exchange. December 3. Attendance 40.

Modern Methods of Commercial and Industrial Lighting, by E. L. Sholl, District Representative, Holophane Glass Co. December 7. Attendance 64.

University of Pittsburgh

Electricity in Coal Mining, by J. J. Crawford, student, and

Automatic Railway Substations, by H. A. Reitmeyer, student. November 4. Attendance 49.

Synchronous Rectifiers, by T. A. Graul, student, and

Application of Inductance Voltage Regulation to Long Distance Lines, by H. R. Jones, student. November 18. Attendance 37.

Princeton University

R. W. MacGregor, Chairman, spoke on his experience in the General Electric Company's Testing Department last Summer. Two reels, entitled "The Electrical Giant," and one reel on power transformers were shown. November 17. Attendance 12.

Rhode Island State College

Narragansett's Company's Generating Station in Providence, by C. H. Thomas, Narragansett Electric Lighting Company. Illustrated with slides. November 17. Attendance 17.

Inspection trip to Generating Plant of the Narragansett Electric Lighting Company, Providence. November 19. Attendance 18.

W. G. Johnson, student, gave an outline of trip to the Plant of the Narragansett Electric Lighting Company. V. E. Murphy was elected Safety Representative. November 25. Attendance 17.

Rose Polytechnic Institute

How to Arouse More Interest and Enthusiasm in the Branch Organization. Open discussion. C. C. Knipmeyer, Counselor, gave a short talk on electrical show to be sponsored by the Branch in April. November 9. Attendance 37.

What the Technical School Should Do for the Engineering Student in the Opinion of the Professional Engineer, by J. B. Smith, student;

Relation between Inventor and Manufacturer, by C. Cash, student, and

Organization and Purpose of the A. I. E. E., by G. Garmack, student. November 16. Attendance 41.

Report on the Morning Session of the Regional Meeting in Chicago, by James Payne. Report on the afternoon session was given by Arthur Drompp. C. Cash, student, gave a report on the discussions held on papers at the meeting. November 30. Attendance 49.

Rutgers University

Application of the Electric Drive in Paper Mills, by A. U. Welch, student; and

Planning for Future Growth of Telephone Lines, by F. Chatten, student. November 21. Attendance 18.

University of Santa Clara

Steam Railroad Electrification. Illustrated with slides. Furnished by the Westinghouse Elec. & Mfg. Co. Read by C. E. Newton. November 29. Attendance 79.

Automatic Sub-Stations, by P. B. Garrett, Westinghouse Elec. & Mfg. Co. Illustrated with slides. December 6. Attendance 82.

University of South Dakota

Motion picture, entitled "Electrified Travelog," was shown. November 16. Attendance 18.

Stanford University

Relays and Automatic Equipment, by Mr. Malarky, General Electric Co. Two-reel motion picture. Models of relays and automatic switches. December 1. Attendance 24.

Swarthmore College

Diesel Engines, by Mr. Morgan, Westinghouse Electric & Mfg. Co. Moving pictures. November 10. Attendance 30.

Syracuse University

Business Meeting. September 28. Attendance 8.

Business Meeting. October 12. Attendance 9.

Boulder Dam Project, by J. S. Walsh, and

Power Situation in New York State, by E. H. Gilchrist. October 21. Attendance 11.

Power Generation in New York City, by R. E. Schwarting, and

Power Distribution in New York City, by K. N. Eastwood. October 28. Attendance 10.

Types of Generating Stations, by R. C. Miles, and

Carrier Circuits in Telephony, by A. L. Helfer. November 4. Attendance 11.

West Penn Power Company, by B. F. Loren, and

New Nine Element Oscillograph, by A. G. Belle. November 11. Attendance 10.

Roosevelt Dam Project, by E. D. Lynde, and

Utilizing Tides for Power, by F. J. Plant. November 18. Attendance 11.

A. & M. College of Texas

Film, entitled "The King of the Rails," was shown. Short talk by C. C. Yates, Counselor, concerning Safety Campaign to be conducted among Student Branches of the A. I. E. E. November 18. Attendance 42.

University of Texas

Motors and Controls, by Mr. Prout, General Elecric Co. November 9. Attendance 33.

Virginia Military Institute

Motion picture, entitled "From Coal to Electricity," was shown. The following officers were elected: President, F. Barkus; Secretary, E. F. James. November 22. Attendance 25.

Motion picture, entitled "King of the Rails," was shown. December 5. Attendance 56.

State College of Washington

Advice to Undergraduates, by R. Cooper, '25, Sales Engineer, Westinghouse Electric & Mfg. Co., and

Report on the Sections Committee Conference and Conference on Student Activities at Summer Convention, by Prof. R. D. Sloan, Counselor. Louis Deleau chosen to succeed Mr. Martin as Vice-President. October 19. Attendance 26.

General discussion on student papers. It was agreed that the presentation of papers by students is very desirable. November 4. Attendance 30.

The Oscillograph, by O. E. Osburn, Instructor in Electrical Engineering. Illustrated by slides. November 17. Attendance 31.

Washington University

Business Meeting. December 1. Attendance 24.

Trip to Bell Telephone Building, St. Louis, to inspect automatic switching equipment, and apparatus for transmitting pictures by wire. December 5. Attendance 30.

University of Washington

The Conditions Under Which the Student Works at the General Electric Company, by W. Joyce, student. November 11. Attendance 60.

The New Great Northern Cascade Tunnel and Its Construction, by R. W. Barker, student. November 18. Attendance 29.

Electrification Statistics, by R. Beeuwkes, Elec. Engr., C. M. & St. P. R. R. Illustrated by slides. December 2. Attendance 40.

Washington and Lee University

Automatic Telephony, by R. E. Kepler, student. General discussion of the condition at Washington and Lee University. November 21. Attendance 8.

Business Meeting. December 2. Attendance 8.

West Virginia University

Radio Beacon Helps Fliers, by H. I. Burner; Automatic Control for Steam Railways, by J. R. Cooke; Niagara Falls, by Ivan Vannoy; Arrester Protection for Watt-Hour Meters, by D. E. Akins; Electrification of Steam Railways in the Lumber District, by John Tinivelli; Rehabilitation of South Shore Line, by H. M. Brosius, and New Electrolytic Process for Zinc Production, by Earl Milam. November 14. Attendance 32.

Seventy-Five Million Dollars to Save Twenty Minutes, by S. J. Donley, and

The Place of the Synchronous Motor in Industry, by R. N. Kirchner. Arrangements made for Electrical Department's float in Thanksgiving Day parade. November 21. Attendance 34.

Worcester Polytechnic Institute

Continuous Threads of Activity, by Prof. V. Karapetoff, Cornell University. He also read a poem which he has written, entitled "The Immigrant." November 28. Attendance 150.

University of Wyoming

Business Meeting. November 15. Attendance 7.

Yale University

Discussion of plans for exhibition to be held December 11-12. Mr. Foulds reported for the Exhibition Committee. Mr. Frank reported for the Advertising Committee. Prof. A. E. Knowlton gave a brief history of the exhibition. Chairman W. J. Brown spoke on the Regional Meeting which will be held in New Haven next Spring, at which time a Student Convention will be held. October 25. Attendance 21.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is adminstered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, NOV. 1-30, 1927

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

ZAHIGKEITSMESSUNGEN AN FLUSSIGKEITEN UND UNTERSUCHUNGEN VON VISKOSIMETERN.

By S. Erk. Berlin, V. D. I. Verlag, 1927. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, heft 288). 54 pp., diagrs., tables, 11 x 8 in., paper. 6,-r. m. V. D. I. members 5,40 r. m.

The purpose of these investigations was the construction of a viscosimeter with an absolute scale, for basic measurements, and the examination of viscosimeters in practical use. A standard viscosimeter was constructed, with which the viscosity of aniline and various oils was measured at various temperatures. With this standard the exactitude and fields of usefulness of the Eugler viscosimeter and other commercial types were then investigated and a formula derived for the conversion of measurements with them into absolute measurements.

VALUATION, DEPRECIATION AND THE RATE-BASE.

By Carl Ewald Grunsky. 2nd edition. N. Y., John Wiley & Sons, 1927. 500 pp., tables, 9 x 6 in., cloth. $5.00.

Dr. Grunsky has revised and extended his analysis of the valuation problem in this new edition. New chapters on "The standard of value," on some "Elements deserving special consideration when rates are to be fixed," and on "A few recent court decisions" have been added, and the tables have been increased in number and made more accurate.

SCHIESS UND SPRENGSTOFFE.

By Ph. Naoum. Dresden u. Lpz., Theodor Steinkopff, 1927. 199 pp., illus., 9 x 6 in., paper, 12,50 r. m.; bound 14.-r. m.

A monograph upon the manufacture of modern explosives in which developments during and since the World War are sys-

tematically presented, with ample references to the original publications.

Rotary Converters.

By E. P. Hill. N. Y., D. Van Nostrand Co., 1927. 329 pp., illus., diagrs., tables, 10 x 6 in., cloth. $9.00.

A treatise dealing with the principles and operating characteristics of the rotary converter, written especially for the engineer responsible for the purchase, operation or testing of this machine. The detailed design of converters is therefore omitted, and attention is concentrated upon their constructional features, auxiliaries, methods of operation and control, operating characteristics, testing, advantages, etc. The book is provided amply with illustrations and a good list of references.

Postponing Strikes; a Study of the Industrial Disputes Investigation Act of Canada.

By Ben M. Selekman. N. Y., Russell Sage Foundation, 1927. 405 pp., tables, map, 8 x 5 in., cloth. $2.50.

The Industrial Disputes Investigation Act adopted by Canada in 1907 has been so frequently pointed to as a model for American legislation to prevent strikes on public utilities that the Russell Sage Foundation undertook a study of its operations. The results of investigations over a period of ten years are contained in the present report. The author discusses the effects of the law, the methods of administration that have proved effective, the attitude of employees and employers and the significance of Canadian experience for the United States.

Neuere Methoden Zur Statik der Rahmentragwerke, v. 2; Der Bogen und das Brückengewölbe.

By A. Strassner. 3rd edition. Berlin, Wilhelm Ernst & Sohn, 1927. 171 pp., diagrs., tables, 11 x 8 in., paper. 12.-r. m.

This book applies modern methods to the calculation of arches and arch bridges, especially those of reinforced concrete. The theory of the elastic arch is first developed and then applied to the calculation of bridge arches. Tables are given which include the influence lines and moments of arches for most cases that occur in practise, which can be used directly for calculation. The design of arches is then discussed and illustrated. The last section treats of the design of successive arches on elastic piers.

Neue Tabellen und Diagramme fur Wasserdampf.

By Richard Mollier. Fifth edition. Berlin, Julius Springer, 1927. 28 pp., 11 x 8 in., paper. Price not quoted. (Gift of Author).

A revised and enlarged edition of Mollier's steam tables, extended over higher pressures and temperatures.

Die Maschinenelemente, v. 1.

By Felix Rötscher. Berlin, Julius Springer, 1927. 600 pp., illus., diagrs., 11 x 8 in., bound. 41.-r. m.

An unusually comprehensive work on machine elements, intended both as a text-book and as a reference work for the designer. The first section gives a general review of the important formulas and principles of the strength of materials; the second, the properties of the various materials. Section three discusses the general principles governing the form of machine elements. Succeeding sections treat of various elements in detail. A useful list of references is included.

Throughout the discussion the author calls attention not only to the calculation of the various elements but also the effects of methods of manufacture and of working conditions upon their form.

Lehrbuch der Metallhuttenkunde, v. 1; Gold, Silber, Platin, Kupfer.

By Victor Tafel. Leipzig, S. Hirzel, 1927. 426 pp., illus., diagrs., plates, 10 x 7 in., paper. 25.-r. m.

The first volume of a modern text-book on metallurgy, planned to give the German student, at reasonable cost, an adequate account of current practise. The author endeavors not only to tell how the metals are being extracted, but why this or that process is in use today. He therefore has tried to make clear the relation of the processes, furnaces and apparatus to the underlying reactions and the working conditions that proceed from them. The commercial viewpoint is also recognized. No room is given to processes no longer used, nor to historical data.

This volume covers gold, silver, platinum and copper. A second will treat of the remaining non-ferrous metals of importance.

Der Kugelschlaghartepruefer.

By J. Class. Berlin, V. D. I. Verlag, 1927. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Heft 296). 20 pp., diagrs., tables, 12 x 8 in., paper. Price not quoted.

Dynamic hardness testers are cheaper and more portable than the static type and have consequently recently again attracted attention. Their advantages have led to this study, which endeavors to throw light upon the principles governing their use by an investigation of the relations between static and dynamic testers.

Kathodenoszillograph. Forschungshefte der Studiengesellschaft Höchstspannungsanlagen . . . . heft 1. Edited by A. Matthias. Berlin, Vereinigung der Elektrizitatswerke e. V., 1927. 77 pp., illus., diagrs., 12 x 8 in., paper. 12.-r. m.

Contains three articles by Dr. D. Gabör on the oscillography of traveling waves with the cathode ray oscillograph and on the use of this instrument in the investigation of protective apparatus for high-voltage lines. The publication is issued by a society for the study of high-tension transmission problems which unite the principal power-plants and electrical interests of Germany.

Examples in the Strength and Elasticity of Materials.

By G. W. Bird. Lond., Edward Arnold & Co., 1927. (Publ. in the U. S. by Longmans, Green & Co.). 196 pp., 8 x 5 in., cloth. $4.00. (Gift of Longmans, Green & Co.).

Presents the subject through a collection of worked problems accompanied by the reasoning leading to the formulas involved. The book covers the instruction necessary to pass the examinations of the various English examining bodies.

Einfuhrung in die Hohere Mathematik.

By Fritz Wicks. Berlin, Julius Springer, 1927. 2 v., 9 x 6 in., bound. 24-r. m. each.

A text-book for students of engineering and science, covering the differential and integral calculus, differential equations, series, analytical geometry and nomography. The book in intended to give a sound theoretical training in mathematics while connecting the theoretical discussions with practical problems; and to provide practise by using the general theory in the solution of physical, chemical and technical problems.

Alluvial Prospecting.

By C. Raeburn and Henry B. Milner. Lond., Thomas Murby & Co.; N. Y., D. Van Nostrand Co., 1927. 478 pp., illus., plates, diagrs., 9 x 6 in., cloth. 36s. (Gift of Thomas Murby & Co.)

In this book, a geologist and a petrologist of experience have collaborated to produce a comprehensive volume, in which the principles of sedimentary petrology are adapted to the economic requirements of alluvial work.

The authors stress the importance of both geological knowledge and laboratory practise in alluvial prospecting. The general field characters of alluvial and allied deposits are first described. The internal structure and the composition of the various types are then discussed, the origin of their constituent minerals is traced, the methods of transportation and accumulation are reviewed, and the concentration and distribution of the pay-dirt described. Prospecting methods are described in detail, and methods given for field and laboratory investigation of alluvial minerals.

Atlas Metallographicus, Tafel 1-16.

By Heinrich Hanemann and Angelica Schrader. Berlin, Gebrüder Borntraeger, 1927. 2 pts., 11 x 8 in., paper. pt. 1, 7,50 r. m.; pt. 2, 6, 75 r. m.

This publication aims to fill the need for a comprehensive collection of micrographs of the structure of materials which is felt by every metallographic laboratory. It is based on the collection of the Berlin Technical High School, which comprises over 7500 specimens of metals.

The Atlas will appear in thirty parts, each containing eight plates, with eight photographs to the plate. Extreme care has

been exercised in making and reproducing the photographs, and all necessary explanations accompany them. A brief general text is included.

The two parts at hand contain photographs of carbon and alloy steels after various heat and mechanical treatments.

A. S. T. M. TENTATIVE STANDARDS, 1927. Phila., American Society for Testing Materials, 1927. 824 pp., diagrs., 9 x 6 in., paper, $7.00; cloth, $8.00.

The 1927 volume of tentative standards contains 175 specifications for ferrous and other metals; cements; limes; gypsum and clay products; preservative coatings and petroleum products; road, waterproofing and roofing materials; rubber products and insulating materials; textiles; fuels; and timber. It contains all those in force upon September first and supplements the book of Standards by giving the latest thought of the various committees upon specifications which are still on trial.

GEODASIE.

By Gustav Förster. Berlin, Walter de Gruyter & Co., 1927. 122 pp., illus., diagrs., 6 x 4 in., cloth. 1,50 r. m.

A very brief survey of the surveying of countries and of higher geodesy, intended for those who wish a concise account of the principles and the more important calculations.

COURSE IN ELECTRICAL ENGINEERING, v. 1; Direct Currents.

By Chester L. Dawes. Ed. 2. N. Y., McGraw-Hill Book Co., 1927. (Electrical Engineering texts). 589 pp., illus., diagrs., 8 x 6 in., cloth. $4.00.

This textbook begins with the most elementary conceptions of magnetism and current-flow and gradually advances to a discussion of the many types of direct-current and alternating-current machinery, transmission devices, etc., that are met in practice. It is planned primarily as an introduction to more advanced textbooks and also for use by engineering students who are not specializing in electrical engineering, but has proven popular in electrical engineering courses also. The last use has been recognized in this edition by the inclusion of a more advanced nature. Other changes suggested by experience have been made.

DENKSCHRIFT UBER DIE MASCHINENINDUSTRIE DER WELT. Bestimmt für das Komitee B des Vorbereitenden Ausschusses der Internationalen Wirtschaftskonferenz des Völkerbundes, Berlin-Charlottenburg, Oktober 1926. Verein Deutscher Maschnenbau-Anstalten. 194 pp., diagrs., tables, 11 x 9 in., paper. 7,50 r. m.

An interesting and valuable statistical study of the machinery industry of the world, excluding electrical machinery and boilers. The producing capacity, present production, number of workers, hours of labor, output, wages, export and import, tariffs, prices, etc., as at present and in 1913, are tabulated and compared for the different countries.

DESIGN AND CONSTRUCTION OF DAMS.

By Edward Wegmann. 8th edition. N. Y., John Wiley & Sons, 1927. 740 pp., illus., plates, 12 x 9 in., cloth. $17.50.

The particular point of interest in the new edition of this well-known treatise is the inclusion of a section upon multiple-arch dams, by Dr. Fred A. Noetzli. Descriptions of a number of notable recent dams have also been added, and minor revisions have been made throughout the book.

ELECTRICAL ENGINEERING PRACTISE, v. 2.

By J. W. Meares and R. E. Neale. 4th edition. N. Y., John Wiley & Sons, 1927. 532 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.50.

This book aims to be between the pocketbook of bare data and the highly technical works written for specialists in various branches of electrical engineering. The present volume treats of the transformation, conversion, storage, and distribution of electricity; and its applications to lighting, heating, welding and cutting. The treatment is much augmented, as comparedwith earlier editions, and the text has been entirely rewritten.

ESSAYS ON THE ART AND PRINCIPLES OF CHEMISTRY.

By Henry E. Armstrong. N. Y., Macmillan Co. [1927]. 276 pp., plate, 9 x 6 in., cloth. $4.00.

The essays here brought together have appeared in various magazines and other publications from time to time. While they treat of many topics, they all are concerned with important questions of chemical theory, upon which Professor Armstrong holds opinions that are not in accord with those generally entertained by his colleagues. The charm and vigor of the author's style make reading a pleasure.

GEMEINFASSLICHE DARSTELLUNG DER GESAMTEN SCHWEISSTECHNIK.

By P. Bardtke. Berlin, V. D. I. Verlag, 1927. 280 pp., illus., 8 x 6 in., cloth. 12,50 r. m.

In this book the various processes of welding, by gas, electricity, and alumino-thermy are discussed at length, from the point of view of the practical welder. The apparatus and methods used in each process are described, instructions for becoming a welder are given, the economics of the different processes are discussed, and methods of testing welds are given. A chapter is devoted to accident prevention, and an appendix treats of gas and electric cutting. Numerous illustrations of the applicatons of the different processes are given and the relative suitability of the different methods for various kinds of welding is given special attention.

GENERAL CHEMISTRY.

By Leon B. Richardson. N. Y., Henry Holt & Co., 1927. 812 pp., illus., ports., 9 x 6 in., fabrikoid. $3.75.

A text-book on general inorganic chemistry for college students, intended as a course for those studying chemistry for cultural purposes, and as an introduction to the science for those who intend to become chemists. More illustrative, explanatory and historical material is included than is usual, with the result that the work is unusually readable and clear.

HANDBOOK FOR HIGHWAY ENGINEERS.

By Wilson G. Harger and Edmind A. Bonney. 4th edition. N. Y., McGraw-Hill Book Co., 1927. 1721 + 32 pp., diagrs. tables, 7 x 4 in., fabrikoid. $6.00.

This handboook is intended to supply all the data necessary in the everyday work of highway engineers, including both the information needed for general planning and that required for the detail work of surveying, designing and construction.

The text of this edition has been entirely rewritten. Chapters on road construction and on railroad grade crossing protection have been added. The additions total 700 pages, an increase of 70% over the third edition.

HOLZBRUCKEN.

By K. Schaechterle. Ber. u. Lpz., Walter de Gruyter & Co., 1927. 124 pp., illus., diagrs., tables, 6 x 4 in., cloth. 1,50 r. m.

Although steel and masonry bridges have largely replaced wooden ones, there has recently been a revived interest in the latter in parts of Europe, where the war has disturbed normal conditions. This little book gives a brief, historical survey of the wooden bridge, treats of the principal varieties of wood and their properties, and discusses design, construction, types, etc.

HUMAN MACHINE IN INDUSTRY.

By Richard T. Dana. N. Y., Codex Book Co., 1927. 312 pp., graphs, tables, 7 x 6 in., cloth. $4.00.

Contents: General principles.—Fuel requirements.—Cooling requirements.—Fatigue.—Rest periods.—Economic hours of work.—Relative efficiencies of men and women.—Occupational age limits.—Industrial diseases.—Effect of stimulants on efficiency.—Morbidity.

The contents give a good idea of the scope of this book, which brings together hitherto scattered information of interest to employers and valuable to those attempting to improve industrial efficiency.

INTRODUCTION TO THE MATHEMATICS OF STATISTICS.

By Robert Wilbur Burgess. Bost., Houghton Mifflin Co., 1927. 304 pp., diagrs., tables, 8 x 6 in., cloth. $2.50.

This book by the Senior Statistician of the Western Electric Company, is designed for students, busines statisticians and others who wish a working knowledge of the subject but who are not sufficiently prepared in mathematics to follow abstruse theoretical discussions. To these readers, the book aims to give a general, but elementary outline of the best methods of statistical analysis, with an explanation and discussion of these

methods, in which no mathematical knowledge beyond that acquired in a high-school course is assumed.

LEFAX RADIO HANDBOOK.

By J. H. Dellinger. Philadelphia, Lefax, Inc., 1927. 7th loose-leaf edition. v. p., illus., diagrs., tables, 7 x 5 in., fabrikoid. $3.50.

This handbook is intended to give the novice a clear understanding of the principles underlying radio and, more especially, of those connected with receiving apparatus. It discusses the fundamental principles, the elements of receiving and trans mitting apparatus, the assembling and operating of receiving sets, and antennas, and also supplies a collection of useful data. The handbook has loose leaves and new data may be obtained regularly from its publisher, for insertion.

LIGHT.

By F. Bray. Lond., Edward Arnold & Co., [N. Y. Longmans, Green & Co.] 1927. 284 pp., illus., ports., diagrs., 8 x 5 in., cloth. $2.25.

An elementary text-book for use in secondary schools, intended to satisfy the requirements of a general education and also to prepare the student for further study of the subject.

MECHANICS OF MATERIALS.

By George Young, jr., and Hubert E. Baxter. N. Y., Macmillan Co., 1927. (Engineering Science series). 451 pp., diagrs., 9 x 6 in., cloth. $4.00.

An introduction to the mechanical aspects of construction, intended to emphasize general principles and to give the student a working knowledge of the theory underlying the design of structures.

OVERHEAD ELECTRIC POWER TRANSMISSION ENGINEERING.

By William T. Taylor. Lond., Charles Griffin & Co., Phila., J. B. Lippincott Co., 1927. 532 pp., illus., diagrs., tables, 9 x 6 in., cloth. $17.50.

A sound practical treatise on overhead line construction and use. A wide range of subjects is covered and the electrical and mechanical principles involved are clearly explained. Illustrations of current practice are used freely and many useful tables are given.

OVERHEAD SYSTEMS REFERENCE BOOK. 1927.

By a Special Committee of the Overhead Systems Committee, Engineering National Section, National Electric Light Association. N. Y., National Electric Light Association, 1927. 572 pp., illus., diagrs., tables, 11 x 8 in., fabrikoid. $7.50; to N. E. L. A. members, $5.00.

A revision of the "Handbook on Overhead Line Construction," with additional data collected since its publication. It presents descriptions of the apparatus, material, methods and principles involved in the construction of overhead electric lines, with formulas for solving electrically and mechanically various problems of transmission and distribution.

PRINCIPLES OF CHEMICAL ENGINEERING.

By William H. Walker, Warren K. Lewis and William H. McAdams. 2d edition. N. Y., McGraw-Hill Book Co., 1927. (Chemical Engineering series). 770 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

This volume first reviews the principles of stoichiometry. Following this, the phenomena accompanying the flow of heat and the flow of fluids, with the laws governing them, are considered in detail. Fuels and their efficient combustion are then discussed, after which processes of crushing and grinding, of mechanical separation and of filtration are described. Evaporation, drying, distillation and the other processes depending upon vaporization are finally treated. Throughout, the scientific principles underlying practical methods are emphasized, and the reader taught how to apply them to specific problems.

PRINCIPLES OF RADIO COMMUNICATION.

By John H. Morecroft. 2d edition. N. Y., John Wiley & Sons, 1927. 1001 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.50.

An excellent general text-book covering the theory of radio telegraphy and telephony and illustrating the application of this theory in practice. This edition has been thoroughly revised in the light of progress since the previous issue. Much of the earlier matter has been deleted and much new matter has been added; the result being a much more thorough and complete text.

ROBINSON'S MANUAL OF RADIO TELEGRAPHY AND TELEPHONY FOR USE OF NAVAL RADIOMEN.

By Rear Admiral Robison, revised by S. C. Hooper and T. A-M. Craven. 7th edition. Annapolis, Md., U. S. Naval Institute, 1927. 737 pp., illus., diagrs., tables, 10 x 7 in., cloth. $5.50.

Robison's Manual, first published in 1907, is intended for student operators and others who wish an account of the elementary principles of the art and descriptions of the apparatus commonly used. In this latest edition the theory of radio communication is set forth in the first section. A second section deals with the transmission and reception of radio signals and with the radio compass. Radio measurements and precision instruments are discussed in a third section. A set of useful tables is included.

SOUND, A PHYSICAL TEXT-BOOK.

By E. G. Richardson. N. Y., Longmans, Green & Co., 1927. 286 pp., 9 x 6 in., cloth. $6.00.

Covers the requirements of university students who have some knowledge of physics and of elementary calculus, while at the same time it offers the research worker and technician an account of recent important investigations, with references to almost all complete papers since 1907. It is a good summary of the results of recent experimental research.

STORY OF CHEMISTRY.

By Floyd L. Darrow. Indianapolis, Bobbs-Merrill Co., 1927. 528 pp., illus., port., 9 x 6 in., cloth. $4.00.

A popular work on chemistry and its modern industrial and scientific achievements. Starting with a history of the development of the science, the author discusses achievements in the use of fuels; in agriculture, war and disease prevention; rubber; colloids; metallurgy; and the synthesis of chemicals. The book is readable and entertaining.

TASCHENBUCH DER DRAHTLOSEN TELEGRAPHIE UND TELEPHONIE

By F. Banneitz. Berlin, Julius Springer, 1927. 1253 pp., illus., diagrs., tables, 8 x 5 in., cloth. 64,50 r. m.

Like most engineering pocket-books, this is the work of a group of specialists. It covers the entire field of radio-telephony, as well as the physical and technical principles of related subjects, and attempts to bring together in one volume all the data commonly needed by the radio engineer, research worker and operator. It would undoubtedly prove valuable to everyone in its field.

TECHNICAL METHODS OF ORE ANALYSIS FOR CHEMISTS AND COLLEGES.

By Albert H. Low. 10th edition. N. Y., John Wiley & Sons, 1927. 348 pp., 9 x 6 in., cloth. $3.50.

A collection of tested methods for the determinations usually required of the technical chemist. Very exact, detailed directions are given. This edition has been revised and some new matter added.

THERMODYNAMISCHE GRUNDLAGEN DER KOLBEN-UND TURBO KOMPRESSOREN.

By Adolf Hinz. 2nd edition. Berlin, Julius Springer, 1927. 68 pp., diagrs., charts, 12 x 9 in., bound. 25.-r. m.

These charts give quick, reliable answers to the complicated calculations that arise in designing compressors, and give the designer and testing engineers the bases for calculations about sizes and relationships in convenient graphic form.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

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53 West Jackson Blvd., Room 1736, Chicago, Ill., A. K. Krauser, Manager.
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MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

LARGE MANUFACTURER of railway signalling and automatic train control apparatus, desires 3 technical graduates, who have had from 2 to 4 years' experience with a manufacturing concern or with a development laboratory in the design or development of small electrical apparatus such as small motors, relays, automatic telephone apparatus, and supervisory control apparatus. Thorough grounding in mathematics, physics, and the fundamentals of electrical engineering is required. Apply by letter. Location, East. X-3761-C.

MEN AVAILABLE

ELECTRICAL ENGINEER, 32, single, desires position with engineering concern or public utility. Six and a half years' experience in power-plant and substation design. Speaks foreign languages. Available on short notice. Location, East or Middle West. C-2710.

RECENT GRADUATE, B. S. in E. E. 22, single, good health, desires position with a Utility Company or Manufacturing Company having interests abroad. Location preferred, Eastern States, Canada or South America. Willing to work hard and conscientiously. Good references. Available immediately. C-3795.

SUPERINTENDENT, A. S. M. E., A. I. E. E., 36, married, 14 years' experience covering railroad location and construction, design and installation of water works, power plants, sewage, canals; county and city engineers; industrial surveys; town planning, street and highway construction. Location, anywhere, Tropical preferred. C-3375.

EXECUTIVE, A. S. M. E., A. I. E. E., A. S. C. E., 48, American, single, graduate engineer, last ten years chief engineer, technical advisor, lately director, leading American corporation manufacturing hardware tools and steel. 26 years' successful experience; executive, production manager, engineer, designer, leading American, foreign manufacturing plants, steel works. Developed new lines, processes; negotiated important contracts. Widely traveled; six languages. Location preferred, anywhere. C-1694.

ELECTRICAL ENGINEER, 34, married, ten years' experience, engineering tests, utility electrician and meter expert, High School and College teacher electricity. Asst. Engineer Bureau of Standards. Writing Ability. Salary, moderate. Location, anywhere. B-8193.

ELECTRICAL ENGINEER. Eighteen years' experience. Manufacturing executive and chief engineer. Development and design of apparatus and instruments. Manufacturing methods and processes. Broad experience in organization and administration. American, Christian. B-2721.

ELECTRICAL ENGINEER, 24, married. Graduate B. E. S., 1924. 26 months Westinghouse Test. Some business experience. Not afraid of work. 15 days' notice. Location, New York or New England. C-3904.

ASSISTANT EXECUTIVE-ADMINISTRATIVE, 36, married. Well balanced experience; fifteen years covers: industrial surveys, cost analyses, commercial statistics, advertising and administrative control. Seven years' large company servicing subsidiaries and clients. Public utility experience. Prefers administrative or commercial to strictly technical. Location preferred: New England or New York. B-9122.

ELECTRICAL ENGINEER, 27. Four years' experience in electrical construction, distribution and general testing with public utility corporations. Would like some research or development work in New York or vicinity. Available on short notice. B-8751.

SALES ENGINEER, for Far East, technical graduate; mechanical, radio and 3 years' business college, 34, single, speaking several languages, extensively traveled Europe; 2 years in Orient, Manchuria, Japan, India. Desires position in Far East as sales representative or commercial work where his experiences are valuable. C-3917.

JUNIOR DISTRIBUTION ENGINEER, 27, good technical and business training; 7 years public utility field construction, operation, inspection and distribution. Experienced in three-phase change over and other reconstruction work. Location, immaterial. C-3516.

TECHNICAL GRADUATE, 25, single, experienced on development, standardization and repair of instruments and meters desires position here or abroad. C-3911.

ASSISTANT TRANSMISSION OR DISTRIBUTION ENGINEER, 26, married. 1923 graduate; 16 months Westinghouse Test; 18 months distribution engineering, making maps and records, lists and investigations, revamping and new overhead layouts; 20 months Engineering Department planning extensions, electrical calculating, estimating, budget and tax work. Location preferred, East. C-3694.

MECHANICAL AND ELECTRICAL ENGINEER, Cornell graduate, 18 years' experience including efficiency engineering for large industrial paper mill along steam and power production lines; combustion studies, boiler-house rehabilitation, etc.; industrial sales engineer for utility. Prior to foregoing: supervision electrical installations for large electrical manufacturer in Eastern City. B-6764.

PUBLIC UTILITY SALES ENGINEER, 41, married. Experience: 5 years with electrical manufacturer, 8 years construction and 8 years electrical power sales with public utilities. Available one month. C-3919.

PROFESSOR, ELECTRICAL ENGINEERING. Ten years' teaching experience covering all the regular and many specialized electrical courses. Contact with the industry has been broad and covers design, construction and application. Well acquainted with the educational needs of the engineering profession. Change desired because present position does not encourage research. B-7083.

ELECTRICAL ENGINEER, 27, single, graduate electrical engineer, five years' experience: three years in general electric traction work, two years in layout of electric locomotives, desires permanent connection. Employed at present but available on short notice. C-3355.

SALES ENGINEER, ten years electrical sales and sales promotion career. Organizer of salesmen, sales policies and incentive plans. Knowledge of consumer, dealer and jobber requirements. Possesses keen, aggressive mind, convincing personality. Unusual wide acquaintance throughout United States. College graduate. Available January 1st. B-8462.

GRADUATE ELECTRICAL ENGINEER, 34, married, desires position as superintendent of construction with public utility or contractor. Ten years' experience including design and construction of high tension automatic and manually operated substations. Desires permanent position. Middlewest preferred. A-3191.

GRADUATE ENGINEER, B. S. in E. E., 26 years of age, with wide technical training, 2 years drafting and 3 years of law school work, desires position in patent attorney's office or where above training will be valuable. Location: in or about Philadelphia, Pa. C-228.

ELECTRICAL MECHANICAL ENGINEER, 52, married, wide and diversified experience in survey, design, installation and rehabilitation of industrial and power plants coupled with practical knowledge of power plant operations as well as electrical and mechanical construction. New York preferred. B-8327.

ELECTRICAL ENGINEER, 30, married, Columbia engineering degree, four years' experience; 1 year telephone testing, designing, 3 years research, supervision measuring instruments large public utility including high potential testing and refrigeration, desires connection

industrial or public utility for research of original nature or engineering work leading to management. Location, New York City or vicinity. B-8977.

ASSISTANT EXECUTIVE, 30, married, degrees E. E. and B. S. Eight years' diversified experience covering planning, administrative control, estimating, special studies, designing and construction. Seven years' experience in transmission and distribution. One year manufacturing experience. Four years in supervisory capacity. Desires position requiring executive ability. Location, New York. B-7315.

TECHNICAL GRADUATE, 23, with four years' operating experience in generating and substation work, wishes position which will give experience in hydroelectric construction and development field or industrial applications of electrical machinery. Location, New York State. Available, two weeks. C-3909.

LICENSED PROFESSIONAL ENGINEER, MANAGER, SUPERINTENDENT, 46, married. Graduate electrical engineer and Master of Science in engineering, journeyman, machinist and electrician; broad and varied electrical and mechanical experience; plant management, production, design, construction operation; power-plants, substations, transmission and distribution system, special machinery, tools, etc. B-8170.

ELECTRICAL ENGINEER, 39, married, of high reputation, experienced in design and cost calculation of electric lighting and industrial installations, desires connection with organization of consulting engineer or architects. Available January 1, 1928. Location, New York City. B-8609.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED DECEMBER 3, 1927

ALBERT, CHARLES, Cable Inspection, Electrical Testing Laboratories, 80th St. & East End Ave., New York; for mail, Brooklyn, N. Y.

BAKKER, JOHN BEREND, Electrician, Great Western Power Co. of California, 1700 Broadway, Oakland, Calif.

BARR, ROWLAND WALLACE, Electrical Engineering, Bucyrus Co., So. Milwaukee, Wis.

BARTON, CHARLES GAINOR, Foreman, Electric Dept., Ramapo Ajax Corp., Hillburn, N. Y.

*BESSEY, CARLTON EBEN, Electrical Research Engineer, Rathen Mfg. Co., Kendall Sq., Cambridge; res., Somerville, Mass.

BETZ, PAUL LeROY, Research Assistant, Consolidated Gas, Electric Light & Power Co. of Baltimore, Baltimore, Md.

BRADLEY, WILLIAM R., Sales Manager, Missouri Power & Light Co., Excelsior Springs, Mo.

*BRISCOE, LESTER ERNEST, Draftsman, Bucyrus Shovel Co., So. Milwaukee, Wis.

BRYAN, DONALD N., Electrician, First Class, Oregon Short Line Railroad Co., Pocatello, Idaho.

BUCKLAND, LESLIE GIBSON, Chief Engineer, Herbert del Cott Pty., Ltd., 422 Little Collins St., Melbourne, Victoria, Aust.

BYRNS, WILLIAM J., C. W. Greene, 1463 Broadway, New York; for mail, Brooklyn, N. Y.

CHRISTEN, ARNOLD A., Draftsman, Engineering Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.

DEEM, JOHN S. L., Asst. City Engineer, Wanganui City Council, City Engineer's Office, Wanganui, New Zealand.

DETTMER, ARTHUR WALTER, Electrician, Construction Dept., Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

DONOVAN, GEORGE MELVILLE, Electrician, Canadian General Electric Co., Ltd., Toronto, Ont.; res., Winnipeg, Man., Can.

EDENS, JOHN HENRY, Planning Engineer, Western Electric Co., Inc., 397 Hudson St., New York, N. Y.

FARRELL, JOHN BASIL, Tester, Toronto Hydro Electric System, Duncan & Nelson Sts., Toronto, Ont., Can.

FISCHER, REINHARD M. O., Draftsman, Engineering Dept., Bucyrus Co., So. Milwaukee, Wis.

FRANKLIN, HARVEY DWIGHT, Draftsman, Engineering Dept., Bucyrus Co., So. Milwaukee, Wis.

GAILEY, HARRY M., Electrical Engineer, Curlett & Beelman, 1020 Union Bank Bldg., Los Angeles, Calif.

GARLAND, RAYMOND G., Electrical Engineer, Illinois Glass Co., Gas City, Ind.

HALFVARSON, GUSTAF A., Mechanical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Verona, Pa.

HARKER, DONALD COBBAN, General Engineer, Westinghouse Elec. & Mfg. Co., 703 Crocker First National Bank Bldg., San Francisco, Calif.

HELFMAN, SAMUEL JOSEPHS, Sponsor Engineer, Duquesne Light Co., Duquesne Bldg., Pittsburgh, Pa.

*HIND, ROLAND FREDRICK, Electrical Inspector, Transmission Engg. Dept., New York Central Railroad, 466 Lexington Ave., New York; for mail, Ossining, N. Y.

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KROUSE, ARTHUR W., Assistant Store Keeper & Shipper, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

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LYNCH, F. EDWARD, Asst. Engineer, Dept. of Distributing Stations, New York Edison Co., 55 Duane St., New York, N. Y.

MADISON, JOUETTE GRAY, Staunton, Va.

MARTIN, LEROY DICKINSON, Switchboard Specialist, General Electric Co., Pierce Bldg., St. Louis, Mo.

McLEAN, GEORGE EDWARD, Master Mechanic, Power House, Stave Falls, B. C., Can.

MITCHELL, JOHN ALBERT, Electrical Engineer, 71 Coventry St., Kidderminster; res., Aston, Birmingham, Eng.

MITCHELL, JOHN E. MOORE, District Manager, Jeffrey-Dewitt Insulator Co., 412-413 Glenn Bldg., Atlanta, Ga.

MORRISSEY, WILLIAM J., Foreman, Distributing Station Dept., Instructor, School for Distributing Stationmen, New York Edison Co., 44 W. 27th St., New York, N. Y.

NARUHN, RUDOLF, W. N. Sauer Co., 804 Crescent St., Pittsburgh, N. S.; for mail, East Liberty, Pa.

NOTT, LORRIN A., District Manager, Sangamo Electric Co., 1061 Howard St., San Francisco, Calif.

OLSEN, WALTER, Sales Engineer, American Elevator & Machine Corp., 113-115 Cedar St., New York; res., Brooklyn, N. Y.

PIMENTEL, ODILON, Asst. Chief Electrician, Cia. Minera San Rafael y Anexas, Pachuca, Hgo., Mex.

REITER, FRANK PAUL, 1117 N. Commonwealth Ave., Los Angeles, Calif.

RICHARDSON, HENRY MARTYN, Electrical Engineer, General Electric Co., 1 River Road, Schenectady, N. Y.

RIDDLE, ALEXANDER, Inspector, B. C. Electric Railway Co., Vancouver, B. C., Can.

RIGGS, LOYD H., Substation Operator, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

SANDSTROM, EDWARD HERBERT, Engineer, Pacific Tel. & Tel. Co., 430 Bush St., San Francisco, Calif.

SMITH, HAROLD SIDNEY, Pacific States Electric Co., 570 1st South, Seattle, Wash.

*SNEED, DAN H., Transmission Man, American Tel. & Tel. Co., 1113 Nashville Trust Bldg., Nashville, Tenn.

STAINBACK, RAYMOND FRANKLIN, Relay Protective Apparatus Maintenance, Caroline Power & Light Co., Laurinburg, N. C.

SOLTURA, JOSE ANTONIO, Assistant Chief Electrical Engineer, Eastern Cuba Sugar Corp., Central Moron, Pina, Cuba.

SWANBERG, OSCAR AUGUST, Special Worker, Wilson-Maeulen Co., 383 Concord Ave., New York, N. Y.

TEOMMEY, GEORGE HENRY, Jr., Inspector, Brooklyn Edison Co., Inc., 360 Pearl St., Brooklyn, N. Y.

THOMAS, HARRY ELLIOT, Junior Engineer, Dept. of Development & Research, Victor Talking Machine Co., Camden, N. J.

THOMSON, BRIGHT CAREY, Radio Dept. Manager and Engineer, Regina Photo Supply, Ltd., 1924 Rose St., Regina, Sask., Can.

TOROK, JULIUS JOSEPH, Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

VANDERSCHAAF, WILLIAM DAVID, Engineering Assistant, Public Service Production Co., 18 E. Park St., Newark; for mail, Clifton, N. J.

WEMPLE, HORACE R., Jr., Estimator, Claude Neon Lights, Inc., 50 E. 42nd St., New York, N. Y.; res., Elizabeth, N. J.

WEST, FRANK RAYMOND, Operating Engineer, Manila Electric Co., Manila, P. I.

YOGANANDAM, G., Assistant Lecturer, Dept. of Electrical Technology, Indian Institute of Science, Bangalore, India.

Total 57

*Formerly enrolled students.

ASSOCIATES REELECTED DECEMBER 3, 1927

BALDWIN, BENJAMIN W., Manager, Transmission Dept., Pacific States Electric Co., 570 1st Ave. So., Seattle, Wash.

DOUGHTY, HORACE JOHN, Meter Engineer, Ferranti Electric, Ltd., 26 Noble St., Toronto, Ont., Can.

FRANKENBERRY, THOMAS HOWARD, Transformer Engineer, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

MACKEOWN, SAMUEL STUART, Asst. Professor of Electrical Engineering, California Institute of Technology, Pasadena, Calif.

NOCK, HERBERT K., Engineer, General Electric Co., West Lynn Works, West Lynn, Mass.

PARKER, JOHN ACTON, Electrical Engineer, Niagara, Lockport & Ontario Power Co., Jamestown, N. Y.

TODARO, IGNATIUS, 1939 E. 1st St., Brooklyn, N. Y.

MEMBERS ELECTED DECEMBER 3, 1927

ALLEN, ARCHIBALD JOHN, Traffic Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

BICHE, LEON L., Sales Manager, Large Power Transformers, General Electric Co., Pittsfield, Mass.

OSTLINE, JOHN ELLIS, Special Development Engineer, Automatic Telephone Mfg. Co., Milton Road, Edge Lane, Liverpool; for mail, London, Eng.

SCOTT, ALEXANDER THEODORE, Electrical Engineer, Balfour, Beatty & Co., Ltd., 66 Queen St., London, E. C. 4, Eng.

WILLIAMS, SELDEN T., Chief Engineer, Victor Talking Machine Co., Camden, N. J.

TRANSFERRED TO GRADE OF FELLOW DECEMBER 3, 1927

JOHNSON, J. ALLEN, Electrical Engineer, Niagara Falls Power Co., Niagara Falls, N. Y.

MATTHEWS, CLAUDE L., Vice-President & Treasurer, W. N. Matthews Corp., 3722 Forest Park Blvd., St. Louis, Mo.

SLEPIAN, JOSEPH, Research Consulting Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

STIGANT, STANLEY A., Manager, Transformer Dept., Johnson & Phillips, Ltd., London, England.

WAGNER, EDWARD A., Acting Manager, General Electric Co., Pittsfield, Mass.

TRANSFERRED TO GRADE OF MEMBER DECEMBER 3, 1927

ASH, PHILIP P., Chief Signal Draftsman, Louisville & Nashville R. R. Co., Louisville, Ky.

BARMACK, BORIS J., Asst. Engineer of Specifications, Commonwealth Edison Co., Chicago, Ill.

BEEKMAN, ROYCE A., Engineer, General Electric Co., Schenectady, N. Y.

BURNHAM, JOSEPH L., Designing Engineer, General Electric Co., Schenectady, N. Y.

CHU, FU I., Electrical Engineer, Chinese Government Telephone Administration, Shanghai, China.

DAZA, GABRIEL A., Supervising Engineer and Assistant General Manager, Visayan Electric Co.; Assistant General Manager, Visayan Electrical Supply Co., Cebu, P. I.

ENOS, HOWARD A., Distribution Engineer, American Gas & Electric Co., New York, N. Y.

EVANS, THOMAS McK., Section Head, General Electric Co., Fort Wayne, Ind.

FITTING, RALPH U., Valuation Engineer, Los Angeles Gas & Elec. Corp., Los Angeles, Calif.

FOSTER, JOSEPH T., Purchasing Assistant to Vice-President, Public Service Corp. of N. J., Newark, N. J.

MANSFIELD, PERCY B., Electrical Engineer (Sales), Armor Electric Mfg. Co., Jamestown, N. Y.

MARYATT, ELMER F., Assistant Engineer, Pacific Gas & Elec. Co., San Francisco, Calif.

McDONALD, JAMES W., Designing Engineer, Duquesne Light Co., Pittsburgh, Pa.

McMANUS, JOHN A., Confidential Assistant to Dr. Elihu Thomson and Patent Attorney, General Electric Co., West Lynn, Mass.

MESSNER, ROY L., Division Transmission Engineer, Pacific Tel. & Tel. Co., Sacramento, Calif.

MURRAY, W. A., Assistant Professor of Elec. Engg., Montana State College, Bozeman, Mont.

REID, ROBERT, Electrical Valuation Engineer, Great Western Power Co., San Francisco, Calif.

SANDS, HOWARD T., Executive, Electric Bond & Share Co., New York, N. Y.

SCHILLER, AVERY R., Vice-President in charge of Operations, Public Service Co. of N. H., Manchester, N. H.

SISMEY, ERIC D., Station Chief, Powerhouse No. 1, Southern Calif. Edison Co., Big Creek, Calif.

SMITH, MORRIS B., Panel Sales Engineer, Crouse Hinds Co., Syracuse, N. Y.

STEIN, I. MELVILLE, Asst. Sales Manager, Leeds & Northrup Co., Philadelphia, Pa.

WELCH, ALFRED F., Engineer, Fractional H. P. Division, General Electric Co., Fort Wayne, Ind.

WILSON, WILLIAM, Head Switchgear Development Dept., General Electric Co., Witton, Birmingham, England.

WILTSE, STANLEY B., Assistant Professor of Elec. Engg., Rensselaer Polytechnic Institute, Troy, N. Y.

WISE, JOHN S., Jr., Operating Manager, Pennsylvania Power & Light Co., Allentown, Pa.

WRIGHT, RALPH H., General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

ASSOCIATES ELECTED DECEMBER 16, 1927

AGGARWAL, JANKIDAS, Demonstrator in Electrical Engineering, College of Engineering, Poona, India.

ANDRIESSEN, RIENK, Draftsman, Canadian Crocker Wheeler, Ltd., George St., St. Catharines, Ont., Can.

ATTMORE, WILLIAM BARTRAM, Auditorium Engineer, Victor Talking Machine Co., 711 Matson Bldg., San Francisco, Calif.

BATKAY, FRANK, Electrical Tester, Galvanometer Dept., New York Telephone Co., 140 West St., New York; for mail, Brooklyn, N. Y.

BEINDORF, LUCIEN JULES, Electrical Engineer, Western Electric Co., Inc., Hawthorne Sta., Chicago, Ill.

BENNETT, JOHN STEPHENS, Asst. Manager, New York Central Electric Corp., 12 Broadway, Hornell, N. Y.

BORDEAU, SANFORD P., Engineer, Electric Machinery Mfg. Co., 14th & Tyler, N. E., Minneapolis, Minn.

BRODIE, JOHN EARLE, National Electrical Engineering Co., P. O. Box 121, Christchurch, N. Z.

BUCHMAN, AMOS RUGBY, Engineer, East Ohio Gas Co., 1405 E. Sixth St., Cleveland, Ohio.

CANGEMI, JOHN F., 15 Schaeffer St., Brooklyn, N. Y.

CRAFT, JAMES GEORGE, Electrician, Consolidated Mining & Smelting Co., Trail; res., Needles, Arrow Lakes, B. C., Can.

DERRIG, JAMES W., Laboratory Helper, Public Service Gas & Electric Co., Clinton Ave. & 21st St., Irvington; for mail, Newark, N. J.

DORKEY, FRANK CARL, Inspector, Auto Substation, Rochester Gas & Electric Corp., Rochester, N. Y.

EADIE, THOMAS W., Toll & Transmission Engineer, Bell Telephone Co. of Canada, Shepherd St., Toronto, Ont., Can.

ELLERBY, ARTHUR EDWIN, Correspondent, Canadian Westinghouse Co., Ltd., Metropolitan Bldg., Toronto, Ont., Can.

ENRIGHT, JAMES DAWSON, Asst. Engineer, Engineering Dept., National Electric Light Association, 37 W. 39th St., New York, N. Y.

ERDOS, KAROLY F., Substation Designer, Illinois Power & Light Corp., 500 Compton Bldg., St. Louis, Mo.

EVANS, DAVID THOMAS, General Foreman, Power Dept., Granby Consolidated Mining, Smelting & Power Co., Anyox, B. C., Can.

EWING, R. H., Sales Engineer, E. A. Lundy Co., 2021 Portland Ave., Louisville, Ky.

FAIRLAMB, WILBUR FIELD, Div. Supt., Virginia Electric & Power Co., Suffolk, Va.

FARR, JAY EDMONDSON, Squad Leader, Sargent & Lundy, 1412 Edison Bldg., Chicago, Ill.

GARDINER, CHARLES EDWARD, Jr., System Operator, Adirondack Power & Light Corp., Schenectady, N. Y.

GERELL, GORDON WILLIAM, Asst. Senior Substation Engineer, Union Electric Light & Power Co., St. Louis; for mail, Richmond Heights, St. Louis, Mo.

GORDON, KENNETH HICKOK, Asst. Foreman, Office of Electrical Engineer, Pennsylvania Railroad, Altoona, Pa.

GRAHAM, DAVID, Graduate Student, Mass. Institute of Technology, Cambridge, Mass.

GRAYDON, JACK MARTIN, Manager, W. Watson & Sons, Ltd., 55 Ghuznee St., Wellington, N. Z.; for mail, Sydney, Aust.

GREENAWALT, J. F., Publicity Manager, Mountain States Tel. & Tel. Co., 800 14th St., Denver, Colo.

GREENWALD, JOSEF MARTIN, 222 W. 84th St., New York, N. Y.

GUENTHER, WILLIAM FRANK, Electrical Engineer, Hamilton Hydro-Electric System, 12 King St., E., Hamilton, Ont., Can.

HANFORD, DAYTON R., Electrical Installation, Hastings-on-Hudson, N. Y.

HARRIS, EDWARD HARLOW, Asst. Engineer, General Electric Co., River Works, Bldg. 64, West Lynn; for mail, East Lynn, Mass.

HARRISON, WALLACE, Maryville, Tenn.

HARVEY, GEORGE MELVIN, Engineering Assistant, Bell Telephone Co. of Pa., 416 7th Ave., Pittsburgh, Pa.

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HIROHASHI, TAKESHI, Electrical Engineer, Toho Electric Power Co.; International General Electric Co., Schenectady, N. Y.

HOLLOWAY, GILBERT C., Electrical Designing Engineer, Electric Bond & Share Co., 2 Rector St., New York, N. Y.; for mail, Passaic, N. J.

JONES, LLEWELLYN E., Electrical Designer, Philadelphia Electric Co., 10th & Chestnut Sts., Philadelphia; for mail, Ridley Park, Pa.

KENWORTHY, OSWALD EDY, Field Engineer, Electrical Dept., Lehigh Valley Coal Co., Wilkes-Barre; for mail, Kingston, Pa.

KHAN, ZAINUDDIN AHMAD, Electrical Engineer, Punjab Hydro-Electric Scheme, The Fort, Lahore, India.

KIMBARK, EDWARD W., Instructor in Electrical Engineering, University of California, Mechanics Bldg., Berkeley, Calif.

KRAMER, LEOPOLD, 21 Morton Place, Jersey City, N. J.

LANE, ARTHUR HOWARD, Technical Employee, Long Lines Dept., American Tel. & Tel. Co., 125 Milk St., Boston; for mail, Wollaston, Mass.

LANE, RICHARD A., Asst. Inspector, Station Electrical Construction Dept., Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

LAWN, GORDON WALTER, Foreman Electrician, Granby Consolidated Mining, Smelting & Power Co., Anyox, B. C., Can.

LEAHY, JAMES F., Chief Electrician, Northwest Steel Rolling Mills, 4315 9th Ave., N. W., Seattle, Wash.

LEES, HAROLD S., President & Manager, Wheaton Electric Light Co., Wheaton, Minn.

MASELTER, JOHN EDWARD, Superintendent, General Electric Co., Service Shop, 1009 Spruce St., St. Louis, Mo.

McCARTY, ORIN PHILIP, Student Engineer, General Electric Co., Lynn; for mail, West Lynn, Mass.

*McCRACKEN, HENRY J., Jr., Junior Electrical Engineer, Dept. of Water & Power, City of Los Angeles, 207 S. Broadway, Los Angeles, Calif.

MILLER, FRANK D., Inspector, Westinghouse Electric & Mfg. Co., Sharon, Pa.

MORELAND, EDWIN STEPHENSON, Brooklyn Edison Co., Brooklyn, N. Y.

*NASH, RALPH ELIOT, Asst. to Electrical Engineer, Turner Tanning Machinery Co., 65 Walnut St., Peabody, Mass.
NORTON, GEORGE HAROLD, Electric Shop Foreman, So. California Edison Co., Big Creek, Calif.
NOWLAND, ROGER LOVETT, Engineering Assistant, Bell Telephone Co. of Pa., 416 7th Ave., Pittsburgh, Pa.
PANZER, HENRY LOUIS, Testing Engineer, Williamsburgh Power Plant Corp., 200 Kent Ave., Brooklyn, N. Y.
PARK, ROBERT HIRAM, General Engineering Dept., General Electric Co., Schenectady; for mail, Scotia, N. Y.
PIAZZA, FRANK DELLA, Commercial Engineer, Monongahela West Penn Public Service Co., Fairmount, West Va.
PONIATOFF, ALEXANDER M., Designer, Switchboard Engineering Dept., General Electric Co., Bldg. 23, Bay 301, Schenectady, N. Y.
POTTER, MANLEY C., Railway Control Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; for mail, Wilkinsburg, Pa.
RHOADES, CHESTER M., Electrical Engineer, Construction Engineering Dept., General Electric Co., Schenectady, N. Y.
RILLSTONE, CHARLES ERNEST, Foreman Electrician, Transformer Dept., Southland Electric Power Board, Dee St., Invercargill; res., Barwheys, Invercargill, N. Z.
ROTHACKER, CHRIST J., Electrician, General Electric Co., 1009 Spruce St., St. Louis, Mo.
SACKMAN, GILBERT ROY, Instructor, Stuyvesant High School, 345 E. 15th St., New York, N. Y.
SAGSTETTER, PAUL EDWARD, Electrical Foreman, Youngstown Sheet & Tube Co., Indiana Harbor, Ind.; for mail, Chicago, Ill.
SANDAHL, EUGENE L., Meter Dept., Power & Light Dept., City of Austin, Austin, Texas.
SCALISI, FRANK, 222 Moffat St., Brooklyn, N. Y.
SCHMIDT, FRANK RUDOLPH, Junior Engineer, Dept. of Distributing Stations, New York Edison Co., 55 Duane St., New York, N. Y.
SMITH, GEORGE EDWARD, Asst. Engineer, Barker & Wheeler, 11 Park Place, New York, N. Y.
SMITH, JAMES W., Asst. Supervisor, Inspection Dept., Toronto Hydro-Electric System, 12 Adelaide St., E., Toronto, Ont., Can.
SNOW, CHARLES EDWARD, Instructor, Electrical Engineering Dept., Mass. Institute of Technology, Cambridge, Mass.
SPICER, WALTER EATON, Asst. to Chief Engineer, Clark Thread Co., 260 Ogden St., Newark; for mail, East Orange, N. J.
*STEINERT, EMIL, Transformer Engineer, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
STIRLING, JAMES ALEXANDER, Power House Electrician, So. California Edison Co., Big Creek, Calif.
TALBOT, HAROLD, Electrical Foreman, Granby Consolidated Mining, Smelting & Power Co., Mine P. O., Anyox, B. C., Can.
TALSMA, CLARENCE, Electrical Engineer, General Electric Co., 610 Electric Bldg., Omaha, Neb.
TANHAUSER, JOHN A., John H. Busby Co., Detroit, Mich.
TANNER, FREDERICK WILLIAM, Electrical Engineer, General Electric Co., Pittsfield, Mass.
THORGERSON, THORALV EIE, 448 54th St., Brooklyn, N. Y.
VART, A. J., 50 Lexington Ave., New York, N. Y.
VILLANUEVA, LAURO G., Electrical Engineer, "Calles" Dam Construction, Camp No. 1, Pabellon, Ags.; for mail, Mexico, D. F., Mex.
WAHL, FRANK S., Superintendent, Tonawanda Power Co., Robinson St., N. Tonawanda, N. Y.
WENSK, JOSEPH A., Power Dept., Substation Operation, United Railways & Electric Co., Baltimore, Md.
WIGGINS, ALBERT M., Designing Electrical Engineer, Engineering Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
WILCOCK, WATKIN, Draftsman, English Electric Co. of Canada, Ltd., St. Catharines, Ont., Can.
WILLIAMS, STANLEY AUSTEN, Electric Heating Engineer, Lee P. Hynes, 30 Church St., New York, N. Y.; for mail, Elizabeth, N. J.
WILLIAMSON, GEORGE, Jr., Electrical Foreman, General Electric Co. Service Shop, 318 Urban St., Buffalo, N. Y.
WILLNER, HARRY CARL, Electrolysis Engineer, Twin City Rapid Transit Co., 1 So. 11th St., Minneapolis, Minn.; for mail, Mt. Vernon, N. Y.
WOODMAN, GILBERT R., Electrician, First Class, Southern California Edison Co., P. O. Box, 383 Big Creek, Calif.
Total 88.
*Formerly Enrolled Students.

FELLOW REINSTATED DECEMBER 16, 1927

FRANKLIN, MILTON W., President & General Manager, M. W. Franklin, Ltd., 800 S. Beretania St., Honolulu, T. H.

ASSOCIATES REELECTED DECEMBER 16, 1927

PAGE, KENDALL LESLIE, Power Engineer, Luzerne County Gas & Electric Co., Kingston, Pa.; for mail, Newton Highlands, Mass.
BJORGERD, THEODORE, Electrical Engineer, South Sweden Power Co., Sydsvenska Kraft. A. B., Malmo, Sweden.

MEMBERS ELECTED DECEMBER 16, 1927

AUGUSTINUS, PAUL, President & Treasurer, Marquette Electric Switchboard Co., 218-222 W. Austin Ave., Chicago, Ill.
CHANDLER, FREDERICK HUBERT, Dist. Engineer, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont., Can.
CRAIG, CLEO FRANK, Special Representative, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.; for mail, Ridgewood, N. J.
HUGHES, EDWARD RICHARD, Consulting Engineer, 55 John St., New York, N. Y.
STEARN, FRANKLIN A., Telephone Engineer, Bell Telephone Laboratories, 463 West St., New York, N. Y.
WALTON, CHARLES EMMET, Electrical Engineer, E. L. Phillips & Co., 50 Church St., New York, N. Y.
WARNER, HARRY OSCAR, Professor of Electrical Engineering, University of Detroit, Detroit, Mich.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held December 14, 1927, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

ATKINSON, RALPH W., Chief Electrical Engineer, Standard Underground Cable Co., Perth Amboy, N. J.
GRAY, ROY WILLIAM, Telephone and Telegraph Engineer (Staff), Interstate Commerce Commission, Washington, D. C.

To Grade of Member

BATSON, WALTER V., Electrical Engineer, Hollis French and Allen Hubbard, Boston, Mass.
BECK, EDWARD F. W., Electrical Engineer, Westinghouse E. & M. Co., East Pittsburgh, Pa.
BERG, ALBERT L., Engineer, Westinghouse E. & M. Co., Sharon, Pa.
BOUTWELL, W. S., Electrical Engineer, Crown Willamette Paper Co., West Linn. Oregon.
CUTLER, HARRY H., Retired Manufacturer of Electrical Apparatus, Brookline, Mass.
DAVID, EDWARD I., Consulting Engineer, Y Coedcae, Aberdare, S. Wales, Gt. Britain.
DAWES, LYMAN B., Instructor in Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
DIBNER, BERNARD, Electrical Engineer, Burndy, Engg. Co., New York, N. Y.
FERGUSON, GEORGE F., Manager, Electrical Department, Arthur D. Riley & Co. Ltd., Auckland, N. Z.
FREEMAN, FREDERICK S., Supt. of Power, Boston Elevated Railway Co., Boston, Mass.
HARDING, ARTHUR L., Assistant Electrical Engineer, Electric Bond & Share Co., New York, N. Y.
KINDY, WARD B., Assistant Professor of Electrical Engineering, Stanford University, Calif.
KURTZ, WILLIAM O., Chief Engineer, Illinois Bell Telephone Co., Chicago, Ill.
LAMSON, HORATIO W., Engineer, General Radio Co., Cambridge, Mass.
MANSON, D. EDGAR, Vice President, Charles H. Tenney & Co., Boston, Mass.
MINER, DOUGLAS F., Section Engineer, Westinghouse E. & M. Co., East Pittsburgh, Pa.
PASSBURG, VOLMER H. H., Electrical Engineer, U. S. Engineer Office, Wilson Dam, Florence, Ala.
PAYTON, MAURICE J., Mfg. Engg. and Design of Induction Relays, General Electric Co., Fort Wayne, Indiana.
PIERCE, NIKOLA C., Supt. of Elec. Distribution, City of Norwich Gas & Elec. Dept., Norwich, Conn.
RATH, JOHN C., Engineer, W. E. Vogelback, Consulting Engineer, Chicago, Ill.
RICH, A. RALPH, Senior Inspector of Hull Material, U. S. Navy, Schenectady, N. Y.
RICHARDSON, MAX C., Transmission Specialist, Pacific States Elec. Co., San Francisco, Calif.
SARGENT, GUSTAVUS F., Electrical Designer, Stone & Webster, Boston, Mass.
SCHERMERHORN, JOHN L., Chief Engineer, American Transformer Co., Newark, N. J.
SCHNEEBERGER, GROVER B., Elec. Engg. Dept., Cleveland Electric Illuminating Co., Cleveland, Ohio.
SHAFER, W. L., Electrical Engineer, Bell Telephone Co. of Pa., Pittsburgh, Pa.
SILBERT, RICHARD H., Assistant Supt., Philadelphia Electric Co., Philadelphia, Pa.
WEST, JOHN, Member of Firm, Macomber & West, Boston, Mass.
WEST, JOHN WINFREE, Production Manager, General Electric Co., West Lynn, Mass.
WHITNEY, RUSSELL L., Sales Engineer, Westinghouse E. & M. Co., Philadelphia, Pa.
WILLIS, CLODIUS H., Assistant Prof. of Elec. Engg., Princeton University, Princeton, N. J.

APPLICATION FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so nform the Secretary before January 31, 1928.

Ackerly, D. G., Union Switch & Signal Co., Swissvale, Pa.
Ainsworth, A. W., Wm. Ainsworth & Sons, Inc., Denver, Colo.
Albergam, G. H., Brooklyn Edison Co., Brooklyn, N. Y.
Alberti, K. O., Smallwood Electric Co., Kansas City, Kans.

Allen, L. E., Southwestern Bell Telephone Co., Dallas, Texas
Althouse, E. E., Duquesne Light Co., Pittsburgh, Pa.
Antipovitch, B. M., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Archbold, E. J., Dixie Construction Co., Birmingham, Ala.
Askew, M., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Ault, G. W., Louisville & Nashville Railroad Co., Louisville, Ky.
Bailey, P. W., Puget Sound Power & Light Co., Seattle, Wash.
Banks, M. F., Penn-Ohio Power & Light Co., Youngstown, Ohio
Barrett, S. R., B. R. Gale Co., Boston, Mass.
Barshewski, F. A., 811 Walker St., Dickson, Pa.
Bauschman, R. T., Pennsylvania Power & Light Co., Allentown, Pa.
Benington, W. F., (Member), Stone & Webster, Inc., Boston, Mass.
Benner, P. E., General Electric Co., Schenectady, N. Y.
Bickley, G. E., Northwestern Bell Telephone Co., Omaha, Nebr.
Bisset, J., New York & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
Blessington, G. L., New Jersey Bell Tel. Co., Newark, N. J.
Bollinger, P., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Booth, G. H., with Mr. Turner, 2192 7th Ave., New York, N. Y.
Bower, M. J., Syracuse Lighting Co., Syracuse, N. Y.
Bowyer, W. B., Hydro-Elec. Pr. Comm. of Ontario, Niagara Falls, Ont., Can.
Bragg, H. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Brainard, M. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Breck, R. S., Public Service Corp. of New Jersey, Irvington, N. J.
Breese, L. W., Iowa Southern Utilities Co., Centerville, Iowa
Brigman, B. M., (Member), University of Louisville, Louisville, Ky.
Brock, A. E., Byllesby Engg. & Management Corp., Chicago, Ill.
Brooks, R. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bruch, R. R., Commonwealth Edison Co., Chicago, Ill.
Brunner, H. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bulen. A. A., Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Byler, A. E., with Arthur F. Buss, Los Angeles, Calif.
Canzi, F. A., (Member), 85 Glen Ave., Cleveland, Ohio
Carpenter, E. M., New England Tel. & Tel. Co., Providence, R. I.
Case, M. D., Southern California Edison Co., Alhambra, Calif.
Chase, M., Puget Sound Power & Light Co., Seattle, Wash.
Chow, G. C., New York University, New York, N. Y.
Churchman, C. E., Patent Engineer, Washington, D. C.
Clancy, W. J., Puget Sound Power & Light Co., Seattle, Wash.
Clasgens, A. E., Rochester Gas & Electric Co., Rochester, N. Y.
Coe, C. F., Northern States Power Co., Minneapolis, Minn.
Converse, J. L., Puget Sound Power & Light Co., Seattle, Wash.
Cook, P. T., General Electric Co., Denver, Colo.
Cordes, E. G., Consolidated Gas, Electric Light & Power Co., Baltimore, Md.
Cordes, O. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Cotton, K. A., Pennsylvania Power & Light Co., New Castle, Pa.
Craft, A. L., Penn-Ohio Power & Light Co., Youngstown, Ohio
Craven, C. L., Bell Telephone Co. of Pa., Philadelphia, Pa.
Crawford, D. A., Stone & Webster, Boston, Mass.
Croll, R. H., Worthington Pump & Machinery Co., Elmwood Place, Hamilton Co., Ohio
Crossman, A. H., Pacific Electric Mfg. Co., San Francisco, Calif.
Cumming, H. B., New Jersey Bell Telephone Co., Hackensack, N. J.
Cunliffe, P. R., Westinghouse Lamp Co., Bloomfield, N. J.
Curtis, C. E., Alan T. Cooke & Co., Houston, Texas
Dammann, G. E., Hyatt Electric Corp., Evanston, Ill.
Danstedt, R. T., National Carbon Co., Cleveland, Ohio
De Roo, H. D., General Electric Co., Schenectady, N. Y.
de Villiers, I., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Dinsmore, D. G., Southern California Edison Co., Alhambra, Calif.
Dixon, F. C., Hudson Coal Co., Scranton, Pa.
Dixon, M. H., Mass. Institute of Technology, Cambridge, Mass.
Doelp, C. L., Ohio Bell Telephone Co., Youngstown, Ohio
Donald, J. K., Mass. Institute of Technology, Cambridge, Mass.
Dorte, P. H., Gooderham & Worts, Ltd., Toronto, Ont., Can.
Doub, D. V., California-Oregon Power Co., Prospect, Ore.
Downes, T. E., Puget Sound Power & Light Co., Seattle, Wash.
Dreier, T., General Electric Co., Schenectady, N. Y.
Drobeck, J. B., Great Lakes Boat Building Corp., Chicago, Ill.
Dunham, R. W., Consumers Power Co., Owosso, Mich.
Dunham, W. H., United Elec. Lt. & Pr. Co., New York, N. Y.
Dutton, C. E., American Tel. & Tel. Co., Chicago, Ill.
Ecker, A. J., Washington Water Power Co., Spokane, Wash.
Eckert, R. C., Northern Ohio Power & Light Co., Akron, Ohio
Edwards, M. W., Light Dept., City of Pasadena, Pasadena, Calif.
Edwards, W. G., Jr., General Electric Co., Schenectady, N. Y.
Emlen, A. A., American Transformer Co., Newark, N. J.
Enochson, A. R., Polyclinic Hospital, New York, N. Y.
Epstein, M. B., with Mark C. Steinberg & Co., St. Louis, Mo.
Evans, H. W., General Electric Co., Pittsfield, Mass.
Evans, J. W., Crosley Radio Corp., Cincinnati, Ohio
Ferdon, A. C., Electric Storage Battery Co., New York, N. Y.
Fielder, F. D., Worcester Polytechnic Institute, Worcester, Mass.
Fiene, M. E., University of Minnesota, Minneapolis, Minn.
Finnie, H. V., (Member), Ampere Electric, Ltd., St. Catharines, Ont., Can.
Fligg, J. A., John Zimmerman & Sons, Philadelphia, Pa.
Folmer, H. M., 12-14 W. Middle St., Hanover, Pa
Foster, E. L., Ohio State University, Columbus, Ohio
Fox, J., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Freudenberger, P. D., Buffalo General Electric Co., Buffalo, N. Y.
Fuketa, T., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Furuse, M., Westinghouse Elec. International Co., New York, N. Y.
Gainder, M. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Gamel, G. D., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Garbrick, J. H., Pennsylvania Power Co., Greenville, Pa.
Gardner, J. A., Pennsylvania Power Co., Sharon, Pa.
Gaston, J. R., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Geiger, J. M., Buffalo General Electric Co., Buffalo, N. Y.
Getty, P. V. B., Habirshaw Cable & Wire Corp., Yonkers, N. Y.
Gibbons, J. E., Atlantic Refining Co., Philadelphia, Pa.
Gillespie, J. F., (Member), Carnegie Steel Works, Youngstown, Ohio
Golden, H. L., Pennsylvania Power Co., New Castle, Pa.
Gottier, T. L., General Electric Co., Schenectady, N. Y.
Gottshalk, L. G., Counties Gas & Electric Co., Norristown, Pa.
Graham, R. N., Penn-Ohio Electric Co., Youngstown, Ohio
Gray, J. L., Louisville Gas & Electric Co., Louisville, Ky.
Green, T. D., Habirshaw Cable & Wire Co., Yonkers, N. Y.
Gustafson, G. A., Commonwealth Edison Co., Chicago, Ill.
Hamill, S. M., Jr., Union Gas & Electric Co., Cincinnati, Ohio
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Hammond, J. A., National Carbon Co., Inc., Cleveland, Ohio
Hanchett, R. J., Los Angeles Electric Works, Los Angles, Calif.
Hansen, E., Iowa Electric Co., Cedar Rapids, Iowa
Hanson, J. W., Columbia Engineering & Management Corp., Cincinnati, Ohio
Hardie, L. C., 665-32nd St., Des Moines, Iowa
Harker, R. M., Penn-Ohio Power & Light Co., Youngstown, Ohio
Harris, W. C., General Electric Co., River Works, Lynn, Mass.
Hart, G. E., Public Service Co. of No. Illinois, Chicago, Ill.
Hartman, E. D., Liberty High School, Bethlehem, Pa.
Hecker, Alvin, Jr., American Tel. & Tel. Co., Kansas City, Mo.
Heidenreich, G. E., (Member), Columbia Engg. & Mgt. Corp., Cincinnati, Ohio
Heimbach, H. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Hemion, J. R., Jr., Weston Electrical Instrument Corp., Newark, N. J.
Henry, D. E., Westinghouse Lamp Co., Bloomfield, N. J.
Hill, O. W., Penn-Ohio Power & Light Co., Youngstown, Ohio
Hill, R. W., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Hoadley, H. A., Jr., Westinghouse Elec. & Mfg. Co., East Pittsburgh. Pa.
Hochgraf, L. B., Rensselaer Polytechnic Institute, Troy, N. Y.
Hoddy, G. W., Day-Fan Electric Co., Dayton, Ohio
Holbrook, Y. C., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Holman, E. W., Washington University, St. Louis, Mo.
Hooper, N. A., Penn-Ohio Power & Light Co., Youngstown, Ohio
Hoover, C. H., Ohio Bell Telephone Co., Toledo, Ohio
Hough, H. G., Philadelphia Electric Co., Philadelphia, Pa.
Houghton, M. G., Commonwealth Power Corp., Jackson, Mich.
Houlihan, R. P., Westinghouse Elec. & Mfg. Co., Springfield, Mass.

Howell, W. D., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Hunter, E. M., General Electric Co., Schenectady, N. Y.
Hunter, M. I., Pennsylvania Power & Light Co., Hazelton, Pa.
Huntsinger, F. J., Federal Radio Corp., Buffalo, N. Y.
Huth, G. H., Penn-Ohio Power & Light Co., Youngstown, Ohio
Hutley, P. L., Pennsylvania Power Co., Sharon, Pa.
Inteman, W. F., Public Service Electric & Gas Co., Irvington, N. J.
Jacobs, C. E., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Jones, A. V., Buffalo General Electric Co., Buffalo, N. Y.
Kavanaugh, P. E., Commonwealth Power Corp., Jackson, Mich.
Kellar, K. H., Virginia Electric & Power Co., Richmond, Va.
Kelso, R. E., Kelso Electric Co., Arvada, Colo.
Kiech, C. F., Ford W. Harris, Los Angeles, Calif.
Kirkham, E. H., New York Central Railroad, New York, N. Y.
Kirkman, W. L., Pacific Power & Light Co., Pasco, Wash.
Kleinberger, A. J., United Electric Light & Power Co., New York, N. Y.
Kolisch, E., Underwriters Laboratories, New York, N. Y.
Koviak, L. S., Allis-Chalmers Mfg. Co., West Allis, Wis.
Krom, M. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Kulisek, M., Carnegie Steel Co., Ohio Works, Youngstown, Ohio
Kumpel, J., Westchester Lighting Co., Hastings-on-Hudson, N. Y.
Landahl, C. F., Carnegie Steel Co., Ohio Works, Youngstown, Ohio
Langner, F. W., Westinghouse Elec. & Mfg. Co., South Philadelphia, Pa.
Leary, F. D., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Leech, W. A., Puget Sound Power & Light Co., Seattle, Wash.
Lenker, L. E., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Lieb, A. W., New York Edison Co., New York, N. Y.
Lincoln, R. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Lofgren, H. E., Stone & Webster, Inc., Boston, Mass.
Luce, J. A., Reeves Heating Co. & May Automatic Oil Burner Co., San Francisco, Calif.
Lukens, J. P., Philadelphia Electric Co., Philadelphia, Pa.
Lusted, W. R., Penn-Ohio Power & Light Co., Youngstown, Ohio
Madison, L. R., Stevens & Wood, Inc., Youngstown, Ohio
Mahan, H. E., General Electric Co., Schenectady, N. Y.
Malmgren, R. V., Western Electric Co., Hawthorne Sta., Chicago, Ill.
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Poole, A. B., Man. Light & Heat Co., Columbus, Ohio
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Mailed to interested readers by issuing companies

Portable Instruments.—Bulletin GEA-158A, 30 pp. Describes portable instruments for alternating and direct-current testing. General Electric Company, Schenectady, N. Y.

Recording Instruments.—Bulletin 362, 28 pp. Describes Bristol's recording instruments for power plants, and illustrates typical installations. The Bristol Company, Waterbury, Conn.

Railroad Electrification.—Bulletin GEA-150A, 44 pp. Describes the electrification of the Chicago, Milwaukee and St. Paul Railway. General Electric Company, Schenectady, N. Y.

Circuit Breakers.—Bulletin 16, 4 pp. Describes Pacific type MS-1 control mechanism for oil circuit breakers of the vertical plunger type. Pacific Electric Manufacturing Company, 5815 Third Street, San Francisco, Cal.

Laboratory Apparatus.—Bulletin GEA-39, 60 pp. Describes electrical laboratory apparatus and educational service for technical high schools and vocational schools. General Electric Company, Schenectady, N. Y.

History of the Hazard Companies.—Booklet, 12 pp., "Fathers of Industry," is a brief historical sketch of the Hazard companies and their founders covering a period of more than one hundred years. Hazard Manufacturing Company, Wilkes-Barre, Pa.

Alternators.—Bulletin 151, 20 pp. Describes six different types of alternators. Contains tabulations of dimensions for outline prints. The flywheel effect requirements for engine driven alternators is thoroughly explained. The Ideal Electric & Manufacturing Co., Mansfield, Ohio.

NOTES OF THE INDUSTRY

Corning Glass Works Appoints Representative.—The Corning Glass Works has appointed Glenn A. Briggs as representative at 2351 Cambridge Avenue, Chicago, to handle only the sales of Pyrex Power insulators in the middle west territory.

Burndy Engineering Company, Inc., 10 East 43rd Street, New York, has been appointed distributor of "Everdur" a new alloy by the American Brass Company. This material consists of copper, silicon, and manganese, having unusual properties of strength and corrosion resistance. The alloy will be stocked by the Burndy Engineering Company in all basic forms, and the company is also in a position to supply all castings and forgings of this material.

A New Centrifugal Pump Unit.—The type SSU centrifugal pumping units recently brought out by the Allis-Chalmers Company are combined motor and pump units of simple and compact design, the complete units being not much larger than a motor alone. As both the pump and motor parts are built and guaranteed by the same manufacturer there is no divided responsibility. The pumps are built in sizes up to 2½ x 2½ inches and can be used with motors up to seven and a half horsepower.

The Gilby Wire Company has moved to its new plant on Riverside Avenue, Newark, N. J., located between the Riverside and Woodside Stations of the Erie R. R. The new plant has practically twice the floor space previously occupied, and there is ample room for additional buildings, as required. Wilbur B. Driver, president, Walter Gilby, treasurer and William Wind, secretary, were all associated for many years with the Driver-Harris Company, of which Wilbur B. Driver was founder. J. B. Maris, vice-president, electrical engineer and metallurgist, was formerly with the Westinghouse Electric & Manufacturing Company.

Incandescent Lamp Sales.—Sales of incandescent lamps in the United States during 1927 total approximately 320,000,000 large size and 218,000,000 small lamps, according to a review of the electrical industry for the year by John Liston of the General Electric Company. This is an increase of about 8,000,000 or 2½ per cent in the large sizes over 1926 and 16,000,000 or 8 per cent in the small sizes over the previous year. "Sales the past year were the largest in the industry," says Mr. Liston; "In ten years the sale of large lamps has doubled and that of the small lamps has tripled. The year has also seen a noticeable increase in the sales of 10,000 watt lamps, the largest in commercial production, which were developed for motion picture studio use. These big lamps are now being widely used for aviation field lighting."

Copperweld Steel Company in New Plant.—With the removal of its main office from Rankin to its new twenty-acre mill at Glassport, Pa., the Copperweld Steel Company announces that headquarters of both the sales and engineering departments will be at Glassport. The personnel of these departments, as now constituted, is as follows: Robert J. Frank, vice-president in charge of sales; Stanton Hertz, formerly electrical engineer, becomes sales manager; Rolf Selquist, formerly assistant electrical engineer, has been appointed electrical engineer; Wm. Jay McIlvane has been appointed district manager with headquarters at New York. Erich G. Elg becomes district manager with headquarters at Chicago. S. H. Burr, formerly inspector and line material specialist at both the Buffalo and New York offices of the Graybar Electric Company, has joined the engineering department of the Copperweld Steel Company, with headquarters at New York.

Review of 1927 and Outlook for 1928.—Gerard Swope, president of the General Electric Company, in reviewing business conditions for the past year and commenting on the outlook for 1928 recently said: "The electrical manufacturing business for 1927 has, on the whole, been satisfactory, and about the same in volume as the previous year. The use of electric current in homes and factories has increased 7 per cent over 1926, and with the exception of 1921 has shown an increase each year since 1919 when the index was first prepared, and the consumption in 1927 was more than double what it was in 1919. This is becoming one of the best indices of general and industrial conditions in America. The outlook for 1928, is on the whole, favorable. Economic conditions are sound and the satisfaction of the demand of 120,000,000 people should provide ample business activities with the usual attendant improvement in the art. Earnings of labor have never been so high and with a continuance of good business their earnings should continue and employment become steadier."

William P. Palmer, president of the American Steel & Wire Company since 1889, died at his home in Cleveland, December 17. He was formerly secretary of Carnegie, Phipps & Company, assistant to the president of the Carnegie Steel Company and second vice-president of the Illinois Steel Company. He was also a director of the United States Steel Corporation.

James S. Keefe, Vice-president of the American Steel & Wire Company for twenty-seven years, has been elected its president.

Harvey Hubbell, president of Harvey Hubbell, Inc., Bridgeport, Conn., manufacturers of electrical devices, died on December 17, in that city. Mr. Hubbell had to his credit more than one hundred patents for his inventions in electrical switches and sockets and machine tools. He was born in Brooklyn, N. Y., and received his technical education at Cooper Institute in New York. In 1888 Mr. Hubbell established a small plant in Bridgeport, which has grown steadily to its present imposing dimensions.

At a meeting of the Board of Directors of the company on December 27, Harvey Hubbell, Jr. was elected president and treasurer to succeed his father. He was associated with the elder Hubbell in the management of the business for a number of years. No changes in the established policies of the company are contemplated.